

HETA 2000-0255-2868
Benefis Healthcare
Great Falls, Montana

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PREFACE

The National Institute for Occupational Safety and Health (NIOSH) conducts investigations and studies of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970 (29 USC 669(a)(6)) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

NIOSH also provides, upon request, technical and consultative assistance to Federal, State, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by NIOSH.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Jean Cox-Ganser and Carol Y. Rao of the Field Studies Branch (FSB), Division of Respiratory Disease Studies (DRDS). Other DRDS staff involved in the field work were Michael Berakis, Randy Boylstein, Khaled Elsherbini, Diana Freeland, Christopher Hoffman, Thomas Jefferson, Michelle Johnson, Gregory Kullman, Chris Piacitelli, Terry Rooney, Liesa Stiller, and Daniel Yereb. In addition, the following DRDS staff assisted in the survey: Amber Harton, Steven Game, Kimberly Jo Stemple, Brian Tift, and Michael Beaty. Daniel Lewis, David Weissman, Michael Whitmer, Zhen Zhen Zhuang, and Toni Bledsoe of the Health Effects Laboratory Division performed the analyses for endotoxin, latex allergen and serum immunology. Alan Lunsford, James Arnold and Ardith Grote of the Division of Applied Research and Technology performed the analyses for ergosterol and volatile organic compounds. Ibrahim Heiba assisted with questionnaire preparation and medical aspects of the field work while on an occupational medicine rotation from the West Virginia University Medical School. Frederick McKnight of Turner Building Science, LLC of Danville, Vermont was contracted by NIOSH to assess potential building moisture intrusions and the ventilation systems. Desktop publishing was performed by Terry Rooney.

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Highlights of the NIOSH Health Hazard Evaluation at Benefis Healthcare

NIOSH was asked by Benefis Healthcare to conduct a health hazard evaluation of respiratory health and indoor air quality at their healthcare facility in Great Falls, Montana. Concerns included possible microbial contamination and the implications for exposures during remodeling.

What NIOSH Did

- Conducted a questionnaire survey of Benefis employees, focusing on respiratory health and latex allergies.
- Conducted environmental sampling at 27 sites in the East and West Campus hospitals.
- Made subjective assessments of water incursions throughout the East and West Campus hospital buildings.

What NIOSH Found

- Higher levels of lower and upper respiratory symptoms that improved away from the workplace were reported by East Campus hospital employees, especially those on the upper floors.
- Work-related health outcomes were associated with signs of water incursion.
- Health outcomes were associated with microbiological contamination and ultrafine particle counts.
- The sentinel asthma cases from the East Campus top floor had negative latex allergy tests.
- The East Campus 6th and 7th floors showed amplification of *Penicillium chrysogenum*, suggesting past water incursion.
- Latex allergen was below the limit of detection in air and generally low in dusts.
- The West Campus hospital had higher levels of latex allergen in dust.
- Powdered latex glove use was reported by 6% and powder-free latex glove use by 16.5% of participants, with no differences between campuses.

- Physician-diagnosed latex allergy was reported by 3.2% of participants with no difference between campuses.

What Managers Can Do

- Disseminate the report findings so that employees with respiratory conditions can take action on the need for relocation or environmental intervention.
- Conduct medical surveillance for the early detection of work-related respiratory problems.
- Promptly remediate water incursions and replace all wetted material that can not be dried out in 24 hours.
- Use containment measures during renovations.
- Put in place housekeeping practices that keep dust accumulation at a minimum.
- Stop use of powdered latex gloves by employees by providing both service and healthcare workers with powder-free, and non-latex gloves where appropriate.
- Clean areas shown to be contaminated with latex dust.

What Employees Can Do

- Be aware of symptoms suggestive of lower and upper respiratory problems, asthma and latex allergies and the need for self-referral for medical evaluation.
- Report water incursions to management immediately.
- Use powder-free latex gloves.



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**HETA 2000-0255-2868
Benefis Healthcare
Great Falls, Montana
December 2001**

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SUMMARY

Benefis Healthcare in Great Falls Montana provides tertiary healthcare services for the 200,000 people of North-central Montana. In April 2000 the National Institute for Occupational Safety and Health (NIOSH) received a health hazard evaluation request from the management of Benefis Healthcare to investigate respiratory health and indoor air quality at the healthcare facility. We posed the following questions:

- Does the prevalence of lower respiratory symptoms, upper respiratory symptoms, and asthma differ between the East and West Campus hospitals and the floors within the hospitals?
- Do the levels of biological agents and characterization of particles differ between the sample sites at the hospitals?
- Is there an association between prevalence of lower and upper respiratory health outcomes and environmental assessment for signs of water incursion, levels of biological agents, and particles?
- What is the prevalence of latex sensitivity and latex glove use in hospital employees?
- Are there areas that are acting as reservoirs of latex allergens?

In May and August 2000 NIOSH conducted an investigation at the East and West Campus hospital buildings of Benefis Healthcare. NIOSH administered a health questionnaire and measured levels of various exposures in the air, chair dust and floor dust (culturable fungi, spore counts, ergosterol, endotoxin, dust mite allergen, cockroach allergen, extracellular polysaccharides, β 1-3 glucans, culturable bacteria, cat allergen, latex allergen, mouse urinary protein, particle counts, volatile organic compounds, temperature, relative humidity, and carbon dioxide). Approximately 60% of the workers participated in the survey and 70% in the areas we sampled.

The results and conclusions of the investigation are as follows:

- We documented that building-related respiratory problems were occurring among employees in the Benefis East and West Campus hospitals.
- The diagnosed asthma prevalence was 17.1% compared to 11.4% for the state of Montana.
- Medical records of the sentinel asthma cases from the 8th floor of the East Campus hospital documented both the occurrence of asthma with methacholine challenge and a work-related pattern with the use of serial peak flow spirometry.
- The sentinel cases were not latex asthma since their latex-specific IgE tests were negative.
- We found higher levels of mold on the 6th, 7th and 8th floors of the East Campus.
- Our direct measures of environmental contamination and our subjective assessment also showed positive associations with health outcomes.

- Physician-diagnosed latex allergy was reported by 3.2% of participants, with no differences between the two campuses.
- The reported use of powdered latex gloves was 6% and 8% in the East and West Campus hospitals, respectively.
- The reported use of powder-free latex gloves was 17% in both hospitals.
- The reported use of non-latex gloves was 51% and 34% in the East and West Campus hospitals, respectively.
- Twenty-seven percent and 42% of the East and West Campus hospitals, respectively, reported no glove use.
- Departments with the highest reported use of powder-free latex gloves were Surgery East (52%), Home Care (50%), Housekeeping (43%), Surgery West (38%) and Transitional Care Unit (36%).
- Latex allergen was not detected in the air.
- The highest ventilation duct latex allergen reservoirs were found in 4 West Campus hospital departments.

The following are specific recommendations for this workplace:

- Disseminate the findings of this report so that employees with respiratory conditions can consult their physicians or the employee health department regarding any need for relocation or environmental intervention at work or at home. Prognosis for work-related asthma is improved by early recognition and exposure cessation.
- Conduct medical surveillance for the early detection of work-related respiratory problems, both for appropriate clinical management and to show whether remediations have been effective in preventing new cases.
- Promptly remediate water incursions and replace all wetted material that can not be dried out in 24 hours. Doing so reduces the potential for microbial amplification.
- Use containment measures during renovations that keep exposures to construction dusts and the reservoirs of mold and latex that we identified to a minimum.
- Institute housekeeping practices that keep dust accumulation at a minimum.
- Repair eroded and damaged casing liners in ventilation systems on the West Campus.
- HVAC personnel and infection control officers should review air flow maps (Appendix G) to insure that the airflows observed are in compliance with American Institute of Architects (AIA) and American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) guidelines for airflows required.
- Provide both service and health-care workers with powder-free latex and/or non-latex gloves where appropriate.
- Clean areas contaminated with latex dust.

NIOSH documented that building-related respiratory problems were occurring among employees in the Benefis East and West Campus hospitals. Our direct measures of environmental contamination and our subjective assessment also showed positive associations with health outcomes. Prognosis for work-related asthma is improved by early recognition and exposure cessation. We recommend that medical surveillance is conducted for the early detection of work-related respiratory problems, both for appropriate clinical management and to show whether remediations have been effective in preventing new cases. Prompt remediation of water incursions and replacement of all wetted material that can not be dried out in 24 hours should be carried out. Containment measures should be used during renovations to keep exposures to construction dusts and the reservoirs of mold and latex that we identified to a minimum. Housekeeping practices that keep dust accumulation at a minimum should be set in place.

Keywords: SIC 8062 (General medical and surgical hospitals), indoor air quality, work-related asthma, health care workers, latex allergies, endotoxin exposure, fungal contamination, particle counts

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INTRODUCTION

In April 2000 the National Institute for Occupational Safety and Health (NIOSH) received a health hazard evaluation request from the management of Benefis Healthcare to investigate respiratory health and indoor air quality at the healthcare facility. The hospital administration requested help from NIOSH concerning possible microbial contamination and the implications for exposures during remodeling.

This request led to the first site visit to Benefis in early May 2000. At that time, the 7th floor was being renovated and the 8th floor was slated for renovation in the spring. Recommendations for controlling dust exposures during remodeling were provided at the time of the site visit, and an interim report on environmental assessment results was issued in January 2001 (Appendix A). During this site visit, Benefis management staff and NIOSH investigators agreed to expand the investigation with a second site visit. This would include a cross-sectional questionnaire survey and an environmental survey at both the East and West Campus hospital buildings, and both microbial and latex allergen exposures would be a focus.

The survey took place from August 21 to 28, 2000 and aimed to investigate the associations between respiratory symptoms and conditions, and biological agents. During the survey, the 8th floor was undergoing renovation, and the 8th Medical Department was relocated to the newly renovated 7th floor.

The survey questionnaire included sections on upper and lower respiratory symptoms, asthma, work history, and latex allergy. The environmental survey included area air measurements for culturable fungi, fungal spore counts, culturable bacteria, endotoxin, ergosterol, particle concentrations, volatile organic compounds, carbon dioxide, temperature, relative humidity and latex allergen. Dust was collected for analysis of endotoxin, latex allergen, glucans, culturable fungi, culturable bacteria, extra-cellular polysaccharide (specific for *Penicillium/Aspergillus*),

cat allergen, cockroach allergen, mouse urinary protein, and dust mite allergen. Environmental assessment of current moisture incursions was made using a standardized checklist. A second interim report on particle concentrations was issued in March 2001 (Appendix B).

This report provides the findings from the survey at this healthcare facility and serves to close out this health hazard evaluation request.

BACKGROUND

Benefis Healthcare in Great Falls, Montana provides tertiary healthcare services for the 200,000 people of North-central Montana. There are about 2100 employees primarily on two campuses termed "East" and "West."

The East Campus hospital building is an 8-story facility that houses most inpatient services, including: Cancer Care, Critical Care Units, Heart and Vascular Center, Inpatient Surgery, Maternal/Child Care, Neurodiagnostics, Medical/Orthopedic/Surgical Nursing Units, Emergency Care, a comprehensive laboratory, a pharmacy, x-ray facilities and Senior Care.

The West Campus is approximately 1 mile from the East Campus. The hospital building is a 5-story facility that houses an acute inpatient rehabilitation (Rehabilitation), a Transitional Care Unit (inpatient/subacute), Chemical Dependency, a Psychiatric unit, Ambulatory Surgery, Cancer Care/Radiation Oncology, Convenience Care, a comprehensive laboratory, a pharmacy, x-ray facilities and a therapy center.

The occupational physician at Benefis Healthcare reported that he had a number of new onset asthma cases from the 8th floor (top) of the East Campus hospital, which functions as a general medical floor. These cases had positive methacholine challenge tests, and a number of cases had evidence of a work-related pattern in serial peak flow monitoring. Upon further investigation, he found that the employees on

this floor reported numerous complaints concerning breathing problems, mucous membrane irritation, and headaches dating from the previous 2-3 years. There was a history of water damage (2-3 years prior) with water leaking around the operable windows during heavy rains, as well as significant water damage to the ceiling from roof leaks.

In-wall and bulk fungal sampling results from the May 2000 site visit indicated microbial contamination inside the walls on the 7th and 8th floors and on the ceiling material of the 7th floor of the East Campus hospital building.

The hospital in the previous year had begun phasing out the use of latex gloves, and requested our assistance in surveying the employees for symptoms of latex sensitivity as well as investigating potential latex allergen environmental reservoirs.

Objectives

The overall objective was to investigate the associations between respiratory symptoms and conditions, and biological agents. Specifically, we posed the following questions.

1. Does the prevalence of lower respiratory symptoms, upper respiratory symptoms, and asthma differ between the East and West Campus hospitals and the floors within the hospitals?
2. Do the levels of biological agents and characterization of particles differ between the sample sites at the hospitals?
3. Is there an association between prevalence of lower and upper respiratory health outcomes and environmental assessment for signs of water incursion, levels of biological agents, and particles?
4. What is the prevalence of latex sensitivity and latex glove use in hospital employees?
5. Are there areas that are acting as reservoirs of latex allergens?

METHODS

Study population

The study population for the cross-sectional questionnaire survey consisted of all 2099 current employees listed by the hospital administration in August 2000. This included employees working in facilities other than the East and West Campus hospitals, by management request.

Questionnaire

The questionnaire included sections on upper and lower respiratory symptoms, physician diagnosis of asthma, latex sensitivities, smoking history, and work history at the healthcare facilities (Appendix C). Lower respiratory symptoms were taken from standard, validated questionnaires (IUATLD questionnaire (1, 2) and Venables *et al.* (3)). Questions on onset dates and work-related pattern were included for the respiratory, nasal, and sinus symptoms. The latex allergy questions were modified from Sussman *et al.* (4).

An initial home mailing to 2099 Benefis employees was made on August 9, 2000, eleven days before the site visit. Two cover letters were enclosed in the mailing, one from NIOSH and one from Benefis, explaining briefly the reason for the survey and giving information on the dates of the site visit. During the site visit, NIOSH personnel were available to answer any questions on the questionnaire, to collect completed questionnaires if employees chose to hand them in rather than to mail them back to NIOSH, or to give employees the opportunity to complete the questionnaire during the site visit. From August 21 to August 28, NIOSH staff covered both hospital buildings, all departments and all three shifts. The Benefis administration provided NIOSH with the opportunity to hold a number of morning and lunchtime meetings which were on both campuses to further encourage participation in the questionnaire survey.

We did a second mailing of the questionnaire on September 25, 2000 to 1333 employees who had not

yet returned a completed questionnaire. A third and final mailing of the questionnaire to 959 employees was made at the end of October 2000.

On December 12, 2000 we received a master list of employee telephone numbers from Benefis and began calling 292 non-participants from selected departments, to offer them an opportunity to complete the questionnaire over the phone. The departments were selected based on being in close proximity to the environmental sampling sites. This telephone follow-up effort continued through January 2001 and 71 questionnaires were completed.

After checking the completed questionnaires, telephone calls (at least three attempts) were made to 109 participants to collect missing information pertinent to work-relatedness of respiratory symptoms, symptom onset date, and occupational history at the health facility. We were successful in contacting 70 of the 109 people. At the completion of the survey process, information from 1273 of the 2099 employees had been attained.

Health Outcome Measures

We examined upper and lower respiratory symptoms occurring both in the last four weeks and in the last 12 months, self-reported cases of asthma, and symptoms suggestive of latex allergy. In addition, symptoms were combined into complexes to serve as indicators of asthma. For symptoms during the last 4 weeks, we used questions from Venables *et al.* (3), and for the last 12 months, we used questions from Burney *et al.* (2) Although symptoms are not always specific indicators of single disease processes, they are sensitive and useful indicators of lung health.

We have used them in the absence of objective health data.

We categorized an individual as having “any lower respiratory symptom” if they reported wheezing or whistling in the chest, or shortness of breath, or chest tightness. We defined shortness of breath as an affirmative response to either one of the shortness of breath questions: attack of shortness of breath while not doing anything strenuous, attack of shortness of

breath following strenuous activity, or awoken by shortness of breath. We defined chest tightness as an affirmative response to the question: have you woken up with a feeling of tightness in your chest at any time?

For symptoms that occurred in the last four weeks, we defined an individual as having asthma-like symptoms if he/she had affirmative responses to three or more of nine lower respiratory symptom questions taken from Venables *et al.* (3). This set included questions on cough, wheeze, or chest tightness while running or climbing stairs fast; sleep being broken by wheezing or difficulty breathing; waking up in the morning with wheezing or difficulty breathing; wheezing in a smoky room; and wheezing in a very dusty place.

For lower respiratory symptoms that occurred in the last 12 months, we defined an individual with asthma-like symptoms if he/she reported wheezing, or being awoken by an attack of shortness of breath, or having trouble with their breathing that is never quite right, or having chest tightness when around dusty parts of their house or near animals (5).

Upper respiratory symptom questions included questions on throat irritation (hoarseness, or loss of voice); stuffy, blocked or itchy nose; nasal discharge; sinus pain; postnasal drip; or blowing thick mucus from the nose. We categorized an individual as having “any upper respiratory symptom” if he/she reported having throat, or nasal, or sinus symptoms.

We also investigated the prevalence of symptoms that improved when away from the workplace on vacation, on weekends, or on a day off.

Medical testing

Asthma Case Follow-up

The Benefis occupational physician scheduled eight new onset asthma cases from the East Campus hospital for interview by a NIOSH physician at the Benefis occupational health department. Updates were obtained for the medical records of the six cases who had previously released their medical

records to NIOSH. Two additional cases signed medical releases and we obtained copies of their medical records from Benefis.

After a consent procedure, two tubes of blood were drawn from each patient, centrifuged, and sent overnight on ice to the NIOSH immunology laboratory, where the serum was stored at -80°C until analyzed for latex-specific IgE and specific IgE for atopy assessment. The sera were analyzed using the Pharmacia CAP system (Pharmacia and Upjohn, Kalamazoo, MI). A negative latex-specific IgE was defined as $<0.35 \text{ kU}_A/\text{L}$ (no detectable antibodies) and positive as $\geq 0.35 \text{ kU}_A/\text{L}$ (presence of detectable antibodies). Atopy was defined as having at least one positive test greater than or equal to Class II to any one of the following aeroallergens: house dust mite mix, mold mix, weed mix, tree mix, grass mix, or epidermal mix.

Environmental Survey

Ventilation System Assessment

Visual assessments were made for a number of the central air-handling units at the East Campus hospital and all of the central air-handling units at the West Campus hospital.

The fan operating static pressure differential was measured with a digital manometer (The Energy Conservatory, Minneapolis, MN) that provided pressure differentials in Pascals. We evaluated air-handling capacities using these measurements and a testing and balancing report provided by the maintenance department.

Subjective Assessment Scoring

NIOSH staff evaluated both the East and West hospital buildings for signs of water incursions and moisture damage. Floor plans were used prior to the site visit to select areas, based on department, within these two buildings. These areas were each examined and a standardized assessment sheet was used to rate each area for dampness and potential biological contamination based on five parameters: current signs of moisture, stains, rust, visible mold

growth, and odor. Assessment scores were assigned for 55 departments. Departments such as Housekeeping, Maintenance, Occupational Therapy and Chaplains were not assigned scores because the employees spent time all over the hospital and could not be assigned a single location score. Certain areas assessed on the 1st floor East Campus and the ground floor of the West Campus were not specific enough to link to small departments.

Each area was scored from 0-3 (none to profuse) for moisture, stains, and rust; and from 0-2 (none to profuse) for mold, and 0-2 (none to strong) for mold odor.

A subjective assessment index for each department was created by summing the scores for visible mold, mold odor, water or damp area, visible signs of water stains, or visible signs of rust. This index was then broken into quartiles based on the values of the total score distribution.

Sampling sites

We selected 18 sampling sites on the East Campus, and 9 sites on the West Campus (Appendix D), and two outdoor sites (one at each campus). Selection of the sites for air, chair dust or floor dust sampling took into consideration the number of people potentially exposed, the amount of time of potential exposure, the level of activity in the area and accessibility of the sampling site.

Air sampling

Endotoxin and Latex

Endotoxin is a cell wall component of gram-negative bacteria commonly found in indoor and outdoor environments. Endotoxin can be found in whole organisms or in cell wall fragments.

Natural rubber latex is derived from the milky sap of the rubber tree. Many of the proteins found in natural rubber latex are allergenic.

Replicate integrated long-term air sampling was conducted at 18 sampling sites on the East Campus

and 9 sites on the West Campus with 2-micrometer (μm) pore size, 37-millimeter (mm) diameter polytetrafluoroethylene (PTFE) open-faced cassettes operated at 3 liters/minute (L/min). Sampling time was during the hours of 7 A.M. to 7 P.M. from August 21-27, 2000. The total sampling time for each cassette averaged 3049 minutes. One set of filters was analyzed for latex allergen using a CAP inhibition assay according to Baur *et al.* (6). The other set of filters was analyzed for endotoxin using a limulus amoebocyte lysate (LAL) assay (Kinetic-QCL, Biowhittaker Inc., Walkersville, MD) according to the kit manufacturer's recommended procedures.

Fungi and bacteria

Short-term culturable air samples for fungi and bacteria were collected using N-6 Anderson multiple-hole impactors (SKC, Eighty Four, PA, USA). Malt extract agar (MEA) and R2A plates were used for fungi and bacteria counts and speciation, respectively. Samples were taken for 4 minutes at 28.3 L/min. Concurrent spore trap samples were taken using Air-O-Cell sampling cassettes (SKC, Eighty Four, PA, USA). Spore trap samples were taken for 4 minutes at 15 L/min. The East Campus was sampled on August 22-23 and the West Campus was sampled on August 24-25. One morning and one afternoon sample were taken on each day and one sample was taken during floor vacuuming for a total of 5 sampling events for each site.

Ergosterol

Ergosterol is the major sterol in fungal membranes. Measurement of the molecule may be useful in determining total fungal biomass in the sample. Filter samples (PTFE membrane filter, 0.2- μm pore size, 47-mm diameter) were taken for 3 days (approximately 65 hours) at 16 sample sites at 42.5 L/min. One sample was taken at each sampling site. The filter was weighed and sent to the Division of Applied Research and Technology of NIOSH in Cincinnati, Ohio, for high performance liquid chromatography analyses.

Particle counts

From August 22-27, 2000, real-time datalogging measurements were taken for a 24 hour period at each sample site for particle counts with a Model 1.108 Grimm Mini-aerosol Spectrometer (Grimm Technologies, Douglasville, GA, USA). The instrument measured the number of particles in 15 size fractions (0.30-0.40, 0.40-0.50, 0.50-0.65, 0.65-0.80, 0.80-1.0, 1.0-1.6, 1.6-2.0, 2.0-3.0, 3.0-4.0, 4.0-5.0, 5.0-7.5, 7.5-10, 10-15, and 15-20 μm) at a flow rate of 1.2 L/min.

In addition, ultrafine particle counts were measured with a Model 8525 P-trak (TSI, St. Paul, MN, USA) at each of the sample sites. The P-trak is a condensation particle counter that measures the number of particles per unit volume in the size range of 0.02 to greater than 1 μm at 0.1 L/min. A 10-second averaging period was used. The East Campus hospital was sampled on August 22-23 and the West Campus hospital was sampled on August 24-25. One morning and one afternoon sample were taken on each day and one sample was taken during floor vacuuming for a total of 5 sampling events for each site.

CO₂/temperature/relative humidity

From August 22-25, 2000, real-time datalogging measurements were taken for a single 24 hour period at each sample site for carbon dioxide (CO₂), temperature and relative humidity with a Q-trak IAQ monitor (TSI, St. Paul, MN, USA).

Volatile Organic Compounds (VOC)

Volatile organic compounds (VOCs) are a group of compounds that are present in the indoor environment in an organic-vapor phase. Sources may include building materials, microbial growth, cleaning agents, smoking, perfumes, and solvents.

VOCs were measured for a single 12 hour period at each sampling site on August 24, 2000. In addition, several patient rooms were sampled for 2-4 hours before or during cleaning. Thermal desorption tubes packed with Carbopack Y, Carbopack B and Carboxin 1003 were exposed at 10 cubic centimeter per minute (cm³/min). The samples were sent to the Division of Applied Research and Technology of NIOSH in Cincinnati, Ohio for gas chromatography/mass spectrometry analyses.

VOC concentrations were divided into three categories: not present (value = 0), low concentration (value = 1) and high concentration (value = 2). The values were summed to create a semi-quantitative estimate of total VOC present in a single sample.

Bulk sampling

Ventilation dust

Latex

Vacuum samples were collected in the return ventilation system ducts in closest proximity to designated sampling stations. Samples were collected from the sheet metal surfaces immediately behind the return grille. In one instance, a composite vacuum sample was collected from the top of a metal shelf and from several door ledges because there was no return ventilation system duct to sample in this area. Several vacuum samples were also collected from designated ventilation system filters. The filter was removed from the ventilation system for sampling.

Surface dust was collected using micro-vacuuuming techniques similar to those described by the

American Society for Testing and Materials (ASTM) method D 5775-95 (7). The area to be sampled was masked using a 100 square centimeter (cm²) disposable paper template. Dust was collected using a 37-mm diameter cassette connected by tygon tubing to a high volume sampling pump field calibrated to 28.3 L/min. A 2- μ m pore size PTFE filter was used in an open-faced filter cassette configuration with a notched cowl to aid vacuum collection. Based on the ASTM method, surface dust was collected by micro-vacuuuming within the area of the masking template for a period of two minutes; the ventilation system filters were sampled for a period of 30 seconds to prevent overloading of the cassette. After the surface dust sample was collected, the cassette was inverted so that the collection surface was facing upwards, the pump was turned off, and the cassette was capped. The cassette was then packaged in an individual, sealable plastic bag. The samples were hand carried to the analytical laboratory in NIOSH's Health Effects Laboratory Division in Morgantown, WV. Samples were analyzed using an inhibition assay with IgE antibodies from latex sensitive individuals (6).

Floor and chair dust

We analyzed the floor and chair dust for culturable fungi and bacteria, endotoxin, animal allergens, β 1-3 glucans and extracellular polysaccharide specific for the fungal genera *Penicillium* and *Aspergillus* (EPS-*Pen/Asp*). For floor sampling, 15 sites on the East Campus and 8 sites on the West Campus were selected. For chair sampling, 17 sites on the East Campus and 8 sites on the West Campus were selected.

β 1-3 glucans are polyglucose polymers found in fungi, plants and some bacteria. Glucans are present in most common fungi. Extracellular polysaccharides (EPS) are stable carbohydrates secreted or shed during fungal growth. β 1-3 glucans and EPS are surrogate markers for fungal mass in an environment.

Floor and chair dust were collected onto a 142-mm diameter glass fiber filter (Gelman Type A/E) with a crevice tool, a specialized filter holder and a L'il

Hummer backpack vacuum (100 CFM, 1.5 HP). The filter holder was manufactured from polyvinyl chloride (PVC) and had a 1000- μ m prefilter. The crevice tools and filter holders were cleaned with isopropyl alcohol between each sampling site. Four chairs per sampling site were vacuumed for 1.5 minutes each. The dusts collected from the seats of the four chairs were pooled for analyses. A 0.836 square meter (m^2) floor area was vacuumed for 5 minutes. Total mass collected was assessed.

The dust was partitioned and analyzed for culturable fungi and bacteria (on MEA and R2A, respectively), latex (CAP inhibition assay according to Baur *et al.* (6)), endotoxin (limulus amebocyte lysate assay as described above), β 1-3 glucans and EPS-*Pen/Asp* (enzyme-linked immunosorbent assay according to Douwes *et al.* (8, 9)), and mouse urinary protein and cockroach, dust mite and cat allergens (enzyme-linked immunosorbent assay according to Chew *et al.* (10)). Concentrations were expressed per chair or per floor area. When limited dust was collected from the floor (i.e., less than 0.5 grams), we did not analyze for β 1-3 glucans or EPS-*Pen/Asp*.

Data analysis

All sections of the questionnaire except the work history were in a computer scannable format using Teleforms (Cardiff Software Inc., Vista, CA). The Teleforms software placed the data, after scanning, into a Microsoft® Access database. The data were verified by NIOSH staff using Access forms for each page of the questionnaire. The work history data were entered into an Access database and were verified after entry by a second person.

The environmental data were received from the laboratories in electronic format and were imported into an Access database. Because environmental data are usually lognormally distributed (11), we expressed exposure concentrations in terms of geometric means or natural log transformations. Samples below the limit of detection (LOD) of the analytical method were assigned a value of $(LOD)^{1/2}$.

Exposure measures, outcome measures, and confounders were defined both *a priori* (i.e., prior to

examination of the data) and using *post hoc* (i.e., after examination of the data) determinations. A subset of participant health data was generated to link with the environmental sampling sites based on proximity of departments to sampling sites (see Appendix E for departments). All employees in a department with a sampling site were assigned exposure values from that sampling site.

Statistical analyses were conducted using SAS version 8 software (12) and JMP, version 4 software (13). The significance of the association between exposures and outcomes are reported as probability (p) values. Values less than 0.05 are considered to represent an association that is not likely to be due purely to chance.

Descriptive statistics, such as averages, standard deviations, and proportions were computed to characterize the demographic information of the study population as well as the environmental survey data. Categorical data analysis (e.g., chi-square statistics), analysis of variance, and logistic regression analysis were applied to examine statistical differences between campuses and environmental data for reported respiratory symptoms.

For multivariate logistic models, a stepwise selection procedure was used, with the probability level for both entry into the model and remaining in the model set at $p < 0.10$. Personal factors used in these models included age, gender, smoking category (as current, former or never), tenure, physician diagnosis of asthma, and physician diagnosis of latex allergy. Home factors used in the models included reported visible mold, mold odor, or water damage, in the last 12 months.

RESULTS

Epidemiological

Study population demographics

Across all campus buildings, 1273/2099 (61%) of the employees completed the questionnaire.

The participation from employees in departments housed in the two hospital buildings was 1171/1834 (64%). The participation from buildings other than the two hospitals was lower at 102/265 (38%).

The 36 departments for which we linked environmental sampling data (Appendix E) had 600 respondents, with an equal participation of just over 70% for each of the two Campus hospitals. Within the hospital buildings, participation varied from a low of 20% in a department of 5 to a high of 100% in a department of 17 (Appendix E).

Table 1 shows the gender, mean age, smoking status, and mean tenure for all participants working in the East hospital, West hospital, both East and West hospitals, or other buildings; the same information on participants for the departments linked to the environmental data is shown in Table 2. The employees were predominantly female, former or never smokers, with a tenure of 10 to 13 years.

Health Outcome Measures

Does the prevalence of lower respiratory symptoms, upper respiratory symptoms, and asthma differ between the East and West hospitals and among the floors within the hospitals?

The overall prevalences of lower and upper respiratory symptoms are given in Table 3.

There was no difference in either overall upper or lower respiratory symptom levels, or overall asthma-like symptom complexes between participants who worked in the East and West Campus hospitals

exclusively, in both Campus hospitals, or in other Benefis healthcare facilities (Table 4). Both campuses had considerable levels of symptoms with a third of respondents reporting one or more of wheeze, chest tightness or shortness of breath occurring in the last 12 months. Eighty percent of respondents had upper respiratory symptoms occurring in the last 12 months.

East Campus hospital participants had higher levels of lower and upper respiratory symptoms and asthma-like symptom complexes, that improved when away from the workplace than West Campus hospital participants (Table 4). These differences between East and West hospital buildings in symptoms which improved when away from the workplace were: 15% vs. 6% for lower respiratory symptoms; 38% vs. 18% for upper respiratory symptoms; 8% vs. 2% for Venables' asthma-like symptom complex; and 14% vs. 4% for Burney's asthma-like symptom complex.

These differences for work-related lower and upper respiratory and asthma-like symptom groupings remained statistically significant after using multivariate logistic models to correct for age, gender, tenure, smoking, home leaks, home visible mold, or home mold odors.

We did not find any differences between the campuses in levels of physician-diagnosed asthma. Overall, physician-diagnosed asthma was reported by 18% and 17% of the East and West Campus hospital participants. Post-hire onset physician-diagnosed asthma was reported by 7% of East Campus and 6% of West Campus hospital participants.

We looked at the year of diagnosis for the post-hire onset asthma cases. We found a tight clustering in time of 7 cases diagnosed from 1998 to 2000 in the participants from the East Campus hospital 7th/8th floors (Medical department). This was not unexpected, since the sentinel asthma cases were from this department. During this same time period from 1998 to 2000 only three other departments -- Neonatal Intensive Care (2 cases), Patient Flow (2 cases), and Medical Records (3 cases), had more

than one case of asthma diagnosed. These were all East Campus departments.

Looking at symptom occurrence among floors of the hospitals, we found that the East Campus hospital 6th, 7th/8th floor workers and the West Campus 4th floor workers had the highest reported levels of lower respiratory symptoms that improved when away from the workplace (Figure 1). Physician-diagnosed asthma with post-hire onset was highest for the 5th and the 7th/ 8th floors of the East Campus hospital, and for the 4th floor of the West Campus hospital.

The highest levels of upper respiratory symptoms that improved away from the workplace were from the East Campus hospital 6th and 7th/8th floor participants (Figure 2).

What is the association between prevalence of lower and upper respiratory health outcomes and environmental assessment for signs of water incursion, levels of biological agents and particles?

Lower Respiratory Outcomes

Work-related lower respiratory symptoms in the last 12 months and the last 4 weeks, as well as work-related asthma-like symptom complexes, were positively associated with the subjective assessment score. In models on work-related lower respiratory outcomes adjusted for personal and home factors (Table 5), the four-category subjective assessment score had a doseresponse trend. Compared with the lowest subjective assessment score areas, employees in the departments with the highest subjective assessment scores had odds ratios of 2.1 and 2.4.

The univariate models on air contaminants showed fairly consistent positive associations between overall and work-related lower respiratory symptoms and asthma-like symptom complexes, and endotoxin, ultrafine particles, total culturable fungi, and total fungal spore count. VOC levels were positively associated with work-related symptoms (Table 6). In models including personal and home factors (Table 7), endotoxin was significant for overall lower respiratory symptoms and the asthma-like symptom

complex, while ultrafine particle count was significant for work-related outcomes. Total fungal spore count showed a trend ($p < 0.1$) for work-related asthma-like symptoms.

Of the chair dust measures, culturable *Penicillium/Aspergillus* showed the most consistent positive associations with both overall and work-related lower respiratory health (Table 6). Other significant chair dust analytes were endotoxin, latex allergen, β 1-3 glucans, and EPS-*Pen/Asp*. In the multivariate models (Table 8), culturable *Penicillium/Aspergillus* was a significant risk factor for work-related outcomes as well as for the overall asthma-like symptom complex. Latex allergen was associated with overall lower respiratory symptoms in the last 12 months.

In floor dust univariate models, EPS-*Pen/Asp* and cat allergen showed fairly consistent positive associations with work-related lower respiratory outcomes. Other fungal measures such as β 1-3 glucans, culturable *Cladosporium herbarum* and culturable *Alternaria*, showed associations with both overall and work-related outcomes (Table 6). In the multivariate models on floor dust, EPS-*Pen/Asp* was a risk factor for work-related lower respiratory symptoms and work-related asthma-like symptom complex. β 1-3 glucans showed a trend with asthma-like symptom complex (Table 9).

Upper Respiratory Outcomes

Environmental measures were more associated with work-related upper respiratory symptoms than any symptoms in univariate analysis (Table 10). A similar set of air analytes was significant for upper respiratory symptoms as for lower respiratory symptoms, and these were endotoxin, ultrafine particles, VOC's, total culturable fungi, and total spore count. In multivariate analysis including personal and home factors, ultrafine particles remained a risk factor for work-related upper respiratory symptoms (Table 11).

Culturable *Penicillium/Aspergillus* in chair dust was a risk factor for work-related upper respiratory symptoms, in both univariate (Table 10) and

Multivariate models. Latex allergen in chair dust was associated with overall and work-related upper respiratory symptoms in the last 4 weeks (Table 12).

Multivariate models on floor dust analytes showed Culturable *Penicillium/Aspergillus*, culturable *Cladosporium herbarum* and β 1-3 glucans ($p < 0.10$) as positive risk factors for work-related upper respiratory symptoms. EPS-*Pen/Asp* was associated ($p < 0.1$) with overall upper respiratory symptoms in the last 12 months (Table 13).

Personal and Home Factors

In multivariate models, physician-diagnosed asthma was a strong risk factor for the presence of both overall and work-related lower and upper respiratory symptoms. Physician-diagnosed latex allergy was also a positive risk factor in many of the models.

Employees with no signs of mold or water damage in their homes had a higher risk for work-related lower and upper respiratory symptoms. The employees with water damage or mold in their homes had a higher risk for the presence of the symptoms, but not for the presence of a work-related pattern.

What is the prevalence of latex sensitivity and latex glove use in hospital employees?

For details of latex sensitivity symptom prevalences and glove use by department see Appendix F.

Physician-diagnosed latex allergy was reported by 3.2% of participants. There were no differences in prevalence between the two campuses. By department, the number of employees with physician-diagnosed latex allergy was 1 or 2, with the Laboratory being the only department with three.

Rash, itching, chapping and scaling of the skin when wearing latex gloves were reported by 20% of participants overall. The East Campus hospital had a higher prevalence (24%) than the West Campus hospital (13%). In the larger departments, the highest prevalences were reported from the Intensive Care Unit (48%), 8th Medical department (48%), Emergency Room (42%), Oncology/Medical 6th

(39%), Telemetry (39%), NICU (38%), and Obstetrics (31%).

Red, itchy, swollen hands within 30 minutes or “water blisters” on the hands within a day when wearing latex gloves (indications of allergic contact dermatitis) was reported by 5.6% of participants. This ranged from 6.8% for East Campus hospital to 2.5% for West Campus hospital workers. Emergency room (17.2%), Obstetrics (18.8%), Laboratory (11.6%), and 8th Medical (10.3%) were among the highest prevalence departments.

When wearing or being around others wearing latex gloves, 10% reported itchy red eyes, sneezing, or nasal symptoms, 2.6% reported lower respiratory symptoms and 0.6% reported other acute reactions, including generalized or severe swelling or shock. There were no statistical differences between campuses in these symptoms, although eye and nasal symptom prevalence was 11.7% and 5% and difficulty breathing was 2.8% and 0.6% for the East and West Campus hospitals respectively.

The larger departments with high prevalences of eye and nasal symptoms included Emergency Room (21.4%), Pediatrics (23.5%), Coronary Intensive Care Unit (21.4%), and Surgical Care (East Campus) (25.0%). Breathing difficulty when around latex gloves, was reported by 1 or 2 employees in any one department, except for Pediatrics where 3 employees (17.7%) reported them.

The reported use of powdered latex gloves was 6% and 8% in the East and West Campus hospitals respectively. When the use of powdered latex gloves was reported, it was usually from 1 to 3 employees per department. Four or more employees reported using powdered latex gloves in Housekeeping, Benefis skilled nursing center, and the Progressive care unit.

Powder-free latex glove use was 17% in both Campus hospitals. Departments with highest reported use were Surgery East (52%), Homecare (50%), Housekeeping (43%), Surgery West (38%), and Transitional Care Unit (36%).

The reported use of non-latex gloves was 51% and 34% in the East and West Campus hospitals, respectively. Twenty-seven percent and 42% of the East and West Campus hospitals, respectively, reported no glove use.

Asthma Case Follow-up

The medical records on the sentinel asthma cases indicated that their asthma had been confirmed with methacholine challenge testing. Furthermore the 8th Medical department cases had kept serial peak flow records for many weeks, and a number of the cases had indications of work-related patterns in peak flow measurements.

The serological tests done at NIOSH indicated that none of the asthma cases had positive latex-specific IgE tests, evidence that latex asthma was not the underlying cause of the sentinel case cluster. In addition, none of the asthma cases were atopic.

Environmental

Ventilation System Assessment

Results are provided in Appendix G.

Subjective Assessment Scoring

Overall, the subjective assessment indicated little visible moisture, mold, or mold odors, and the scores were dominated by the signs of stains, either on ceiling tiles or around windows. Where stains were seen, they were mostly assigned as level 1 out of a scale from 0 to 4, and there were no stains given a score of more than 2.

The summed subjective assessment scores ranged from 0 to 20. The quartile cutoffs were 2, 4, and 8. A department was assigned to one of the four categories from low to high if the score was respectively: ≤ 2 ; 3 or 4; 5, 6, or 7; ≥ 8 .

Areas in the highest category in the East Campus hospital were Pediatrics, 8th Medical, NICU and Obstetrics, Coronary Care, Progressive Care, Risk Management, and Surgery area. Areas in the highest category in the West Campus hospital were Laundry,

meeting rooms and offices on the ground floor, and the Short Stay Unit on the 4th floor.

Air and Dust Sampling

Do the levels of biological agents and characterization of particles differ between the sample sites at the two hospitals?

This question is addressed for each of the environmental measures below. Tables are presented in Appendix H.

Endotoxin in air

The geometric mean of endotoxin levels in air across all sampling locations for the East Campus is 1.48 Endotoxin Units per cubic meter (EU/m³) and 1.15 EU/m³ for the West Campus (not statistically different, p-value=0.16). None of the West Campus sampling locations (0/8) and 24% of the East Campus sampling locations (4/17) had endotoxin levels greater than the outdoors.

Indoor endotoxin levels in air ranged from 0.74 to 4.72 EU/m³. The outdoor level was 2.09 EU/m³. Tables H.1 and H.2 show the concentration measured at each sampling site.

Fungi and Bacteria in air

Total culturable fungal concentrations in air were averaged for each sampling site (Table H.1 and H.2). Mean total culturable fungi in air ranged from 14 to 40 Colony Forming Units per cubic meter (CFU/m³) in the West Campus (outdoors = 76 CFU/m³) and 3 to 137 CFU/m³ in the East Campus (Outdoors = 107 CFU/m³) (Tables H.1 and H.2). The fungal species found outdoors were primarily *Cladosporium herbarum*, *Epicoccum*, and basidiomycetes. The indoor fungal types were similar to the outdoors except for the 6th and 7th floors in the East Campus. *Penicillium chrysogenum* was detected in 55% of the samples indoors (6 out of 11 samples taken). The average concentration of *P. chrysogenum* was 77 CFU/m³ on the 6th and 7th floors which accounted for 55% of the fungal species detected. Fourteen percent of outdoor samples (1 out of 7 samples) were

positive for *P. chrysogenum*. The average concentration of *P. chrysogenum* was 1 CFU/m³ which accounted for 1.2% of the total fungal species detected outdoors.

The geometric mean of total fungal spore counts in air ranged from 5 to 1099 spores/m³ (Tables H.1 and H.2). The pattern of distribution between the East and West Campuses and the floors was similar to the culturable fungi results. *Penicillium* and *Aspergillus* spores counts were higher on the 6th and 7th floors of the East Campus than outdoors or in other areas of either campus. (Note: *Penicillium* and *Aspergillus* spores cannot be differentiated via microscopy. Therefore the data are always presented as a *Pen/Asp* grouping.) In some samples on the 7th floor, *Pen/Asp* accounted for more than 80% of the fungal species detected. The concentrations of *Pen/Asp* ranged from 33 to 6667 spores/m³ on the 7th floor.

The geometric mean of total culturable bacteria in air ranged from 52 to 277 CFU/m³ indoors. The most commonly recovered bacteria were gram-positive bacteria, such as *Coryneform* bacteria, *Bacillus*, *Micrococcus* and *Rhodococcus*. The distribution of detected species of bacteria was similar indoors and outdoors.

Ergosterol

Ergosterol concentrations in air were below the limit of detection for the analytical method (LOD = 0.8 ng ergosterol/filter).

CO₂ /temperature/relative humidity

Carbon dioxide (CO₂) levels ranged from 381 to 564 parts per million (ppm). Indoor temperature ranged from 72.6 to 79.6°F and relative humidity ranged from 25.0 to 42.2% (Table H.3). These values are within the range acceptable for a hospital environment.

Particle counts

Overall particle counts on the East Campus were significantly higher than on the West Campus. The geometric mean of ultrafine (less than 1 µm) particle counts in air across all sampling locations for the West Campus was 1485 particles/cm³ and 2427

particles/cm³ for the East Campus. None of the West Campus sampling locations (0/8) and 24% of the East Campus sampling locations (4/17) had ultrafine particle counts greater than the outdoors. Geometric means of ultrafine particle counts measured with a P-Trak (TSI, St. Paul, MN, USA) ranged from 654 to 7164 particles/cm³ (Tables H.1 and H.2). The geometric mean for the outside was 4002 particles/cm³.

Results of the real-time datalogging measurements for particle counts with a Grimm Mini-aerosol Spectrometer are presented and discussed in Interim Letter II, sent to Laura Goldhahn-Konen in January 2001 (Appendix B).

Volatile Organic Compounds (VOC)

A total of 149 different species of VOC's were detected across all of the samples. The range of sums was 45 to 92 indoors and 31 to 38 outdoors. The East Campus VOC levels were significantly higher than the West Campus (p-value < 0.05). Both campuses were significantly higher than the outdoor levels. This method takes into consideration the number of VOC species and the relative concentrations detected.

Floor and chair dust

Dust mite allergen, cockroach allergen and mouse urinary protein were below the limit of detection of the analytical method (Enzyme-Linked Immunosorbent Assay) in the floor and the chair dust samples.

There was no statistical difference in cat allergen concentrations between the East and West Campus hospitals in floor or chair dust (Figures 3 and 4). Cat allergen (Fel d 1) concentrations in the floor dust ranged from 0.02 to 10.89 µg per square meter of floor area (µg/m²) (Table H.4). The geometric mean across all floor sampling sites was 0.56 µg/m². Cat allergen concentrations in chair dust ranged from 3.34 to 180.73 µg/chair (Table H.5). The geometric mean across all chair sampling sites was 22.9 µg/chair.

There was no statistical difference in EPS-*Pen/Asp* concentrations between the East and West Campus hospitals in floor or chair dust (Figures 3 and 4). Concentrations of EPS-*Pen/Asp* ranged from 8.34×10^2 to 5.37×10^4 nanograms of equivalent units per square meter of floor area (ng EqU/m²) (Table H.4). The geometric mean across all floor sampling sites was 5966 ng EqU/m². EPS-*Pen/Asp* concentrations in the chairs ranged from 2.87×10^3 to 3.67×10^4 ng EqU/chair (Table H.5). The geometric mean across all chair sampling sites was 1.04×10^4 ng EqU/chair.

There was no statistical difference in β 1-3 glucans concentrations between the East and West Campus hospitals in chair dust (Figure 4). β 1-3 glucans concentrations were higher in the East Campus hospital floor dust samples (Figure 3). Concentrations of β 1-3 glucans in floor dust ranged from 1.56×10^2 to 2.23×10^4 μ g/m² (Table H.4). The geometric mean across all floor sampling sites was 1.53×10^3 μ g/m². β 1-3 glucans concentrations in the chairs ranged from 6.47×10^2 to 3.82×10^3 μ g/chair (Table H.5). The geometric mean across all chair sampling sites was 1.70×10^3 μ g/chair.

Endotoxin levels were significantly higher in chairs in the West Campus hospital than the East Campus hospital (Figure 4). There was no difference in endotoxin levels in the floor dust (Figure 3). Endotoxin levels in the floor dust ranged from 2.47 to 3246 Endotoxin Units (EU)/m². The geometric mean was 15.3 EU/m². The samples from Radiology and Obstetrics (428.85 and 3246 EU/m², respectively) were one to two orders of magnitude greater than the other samples. The geometric mean across all floor sampling sites was 13.3 EU/m². Endotoxin levels in the chair dust ranged from 0.97 (in Radiology) to 15.87 EU/chair. The geometric mean across all chair sampling sites was 7.74 EU/chair.

There were no significant differences in culturable bacteria concentrations in the floor and chair dust between the West and East Campus hospitals (Figures 3 and 4). Culturable bacteria concentration ranged from 7.7×10^3 to 8.2×10^6 CFU/m² in the floor and 4.4×10^3 to 1.5×10^6 CFU/chair in the

chair samples (Tables H.4 and H.5). *Bacillus* spp., *Coryneform* bacteria, *Micrococcus luteus*, and *Rhodococcus* were the predominant bacteria recovered from the chairs and floors. The overall geometric means across floor and chair sampling sites were 2.9×10^5 CFU/m² in the floor samples and 3.8×10^4 CFU/chair in the chair samples, respectively.

There were no significant differences in culturable fungi concentrations in the floor and chair dust between the West and East Campus hospitals (Figures 3 and 4). Culturable fungi concentrations ranged from 1.0×10^3 to 1.2×10^5 CFU/m² in the floor (Table H.6) and 4.6×10^4 to 2.2×10^5 CFU/chair in the chair samples (Table H.7). *Alternaria alternata*, *Aureobasidium pullulans*, *Cladosporium herbarum*, *Epicoccum nigrum*, *Penicillium chrysogenum* and yeasts (other than *Rhodotorula*) were the predominant fungal species recovered from the floors and chairs. The overall geometric means across floor and chair sampling sites were 4.3×10^4 CFU/m² in the floor samples and 9.5×10^4 CFU/chair in the chair samples, respectively.

Latex allergen in air and dust

Are there areas that are acting as reservoirs of latex allergens?

Latex concentrations in air were below the limit of detection for the analytical method (LOD = 1.48 ng latex allergen/filter).

The West Campus had significantly higher concentrations of latex allergen in ventilation system dust than the East Campus. The highest concentrations were inside the return ducts of the Convenience Care Center, Surgery, Transitional Care and Rehabilitation Departments on the West Campus. Latex allergen concentrations in ventilation system dust ranged from <LOD to 375.88 ng/mg of dust (LOD = 1.26 ng) (Table H.8). Sixty-two percent of the ventilation dust samples were below the limit of detection (21/34).

Latex allergen concentrations in the floor and chair dust were higher in the West Campus hospital than the East Campus hospital, although the differences were not statistically significant (Figures 3 and 4). Latex allergen concentrations in floor and chair dust are presented in Tables H.4, H.5 and H.9. Table H.4 displays latex allergen concentration by floor area (m²) and Table H.5 by chair while Table H.9 presents the concentration per milligram of dust collected. Expressing latex allergen concentrations per floor area (or per chair) may be more relevant to exposures and potential health effect relationships. Latex allergen concentrations ranged from 0.05 to 107.76 ng/m² in the floor and 0.35 to 273.93 ng/chair in the chair samples. The overall geometric means across all floor and chair sampling sites were 1.26 ng/m² and 24.11 ng/chair, respectively. Latex allergen concentrations in chairs did not correlate

well with latex allergen concentrations in floors (Table H.9).

DISCUSSION

This evaluation of respiratory health was undertaken to extend the work of the corporate occupational physician who identified a cluster of work-related asthma cases from the 8th Medical Department of the East Campus hospital. Background information provided by Benefis Healthcare had indicated a history of water incursions on the 8th floor of the East Campus hospital. The hospital management had been proactive in reducing latex usage and in assessing prevalence of latex sensitivity. To augment their assessments, the hospital management requested that NIOSH evaluate latex allergen levels in the East and West Campus hospital buildings and symptoms of latex sensitivity in their employees. In addition, we focused our environmental assessment on biological exposures. We included assessments of animal allergens because of their recognized potential effects on respiratory health (10, 14). Many of our analytical methods are state-of-the-art and are part of our on-going research initiative to clarify the role of biological contaminants in adverse respiratory health outcomes.

The current study documents beyond doubt that building-related respiratory problems were occurring among employees in the Benefis East and West Campus hospitals. The evidence supporting this conclusion is four-fold. First, the prevalence rate of reported physician-diagnosed asthma is elevated compared to state statistics obtained with similar questions (15). The prevalence of diagnosed asthma among the employee respondents was 17.1% compared to 11.4% (95% confidence interval 9.9% - 13.0%) for adults 18 years and older for the state.

The second line of evidence for building-related respiratory problems comes from medical records of the sentinel asthma cases. Their physicians documented the occurrence of asthma with methacholine challenge. Furthermore, work-related patterns were documented with the use of serial peak flow spirometry. We know that these cases were not latex asthma because the NIOSH laboratory tests for latex specific IgE were all negative. We have some indirect evidence suggesting that fungi or dampness problems may have been associated with the cluster. During a site visit in April 2000, we identified potential reservoirs and pathways of microbiological contamination (Appendix A: Interim Letter I). There is substantial epidemiologic evidence that home dampness and indices of mold exposure increase the risk of asthma and respiratory symptoms (16). The same is likely true of dampness and mold exposure in nonindustrial workplaces (17, 18).

The third line of evidence concerns the distribution of upper and lower respiratory symptoms across the East and West Campus hospitals. The proportion of respondents who reported improvement in symptoms when away from work was considerably and statistically higher in the East Campus than the West Campus hospital, even after adjustment for age, gender, tenure and smoking status. There was also evidence of an unequal distribution of health effects within the East Campus hospital with higher levels reported from the 6th and 7th/8th floors. It is unlikely that a higher proportion of susceptible people would work in one part of the healthcare facilities. Rather, the building environment is the most logical causal

factor for the unequal risk of respiratory disease across the two Campus hospitals.

The fourth line of evidence supporting the existence of building-related respiratory problems is the correlation between asthma-like symptoms and upper respiratory symptoms with environmental assessments – both surrogate and direct measures of microbial contamination.

Our surrogate measure of the potential for microbial contamination was the assessment for signs of water incursion, visible mold and mold odor. This index was not only positively associated with work-related lower respiratory symptoms but showed evidence of a dose-response trend after adjustment for personal factors and reported presence of water-damage and mold in homes. Dales *et al.* demonstrated that self-reported mold odor in residential environments was significantly associated with total culturable fungi in dust samples, and that homes with reported visible mold growth also showed higher level of *Aspergillus* spp. and *Penicillium* spp. than those without visible mold (19). Finnish research on the development of classification systems of moisture-damaged dwellings in relation to health effects have found similar positive association with upper and lower respiratory symptoms (20).

Our direct measures of environmental contamination also showed positive associations with health outcomes. In single variable statistical models, several measures of fungal and bacterial contamination were positive risk factors. Endotoxin in the air, ultrafine particles in the air, culturable *Penicillium/Aspergillus* in chairs, EPS-Pen/Asp in floor dust, and latex allergen in chairs remained associated with lower respiratory health effects after adjustment for personal and home factors. Ultrafine particles in the air, culturable *Penicillium/Aspergillus* and latex allergen in chairs, culturable *C. herbarum* and culturable *Penicillium/Aspergillus* in floor dust remained associated with upper respiratory health effects after adjustment for personal and home factors.

Indoor exposures to endotoxin in air or dust have been associated with lower respiratory symptoms (21-23). Endotoxin levels have been measured from 4.50×10^3 EU/m³ to 8.85×10^4 EU/m³, in industrial environments (22-25). Exposures to high concentrations of airborne endotoxin have been correlated with adverse respiratory effects (e.g., acute airflow obstruction) (21, 26). Airborne endotoxin levels have been reported from 0.24 EU/m³ to 180 EU/m³ in indoor environments (27, 28). Reynolds *et al.* found an association between respiratory symptoms and indoor airborne endotoxin exposures (range of 0.5 to 3.0 EU/m³) (29). Our finding that endotoxin in air was a positive risk factor for lower respiratory symptoms adds to the body of evidence suggesting that either endotoxin may have an adverse health effect at much lower levels than previously reported, or may be a marker for the causal contaminants.

Ultrafine particles may have more severe respiratory effects because the small size allows deposition deep in the lungs. There is very little literature linking ultrafine particle exposures and respiratory health effects in the indoor environment. Our finding of positive risk effects for ultrafine particles on work-related lower and upper respiratory symptoms has support from outdoor air pollution research. Wichmann and Peters found that outdoor particles less than 2.5 µm in diameter were related to decreases in lung function (30). In a tertiary teaching hospital in Rochester, N.Y., researchers found a mean particle level of 3.63×10^3 particles/cm³ (particle diameter less than 0.8 µm) that are consistent with our measured levels (31). The researchers discussed that increases in particle counts were related to increases in indoor activities such as operation of vacuum cleaners, coffee machines, centrifuges and computers. They hypothesized that another significant source of particles as originating from ongoing construction outside the hospital.

In our analyses, measures of fungal contamination in the air and the dusts were significantly associated with health outcomes. Some of the most consistent effects were found for culturable *Penicillium/Aspergillus*, culturable *Cladosporium*

and EPS-*Pen/Asp*. There is not much literature linking measurements of fungi in surface dust with respiratory health effects. The implications of surface dust in relation to airborne exposure of biological contaminants is still unknown. Dust may be a marker for prior aerosol exposures. *Cladosporium*, *Penicillium* and *Aspergillus* have been reported in the literature to have allergic effects (18, 21, 32-34). *Penicillium* and *Aspergillus* are often found on chronically damp interior surfaces and have been reported as dominant genera in water-damaged buildings.

In non-problem buildings, the types and concentrations of fungi found indoors are similar to outdoors. In buildings with indoor fungal amplification, the types and concentrations of fungi are different indoors and outdoors. There was evidence of indoor *Penicillium chrysogenum* amplification on the 6th and 7th/8th floors of the East Campus hospital building. This may explain the elevation in reported respiratory symptoms on these two floors. In a study of 48 schools, researchers found that airborne *Penicillium chrysogenum* was associated with sick building syndrome (e.g., itchy eyes, headaches, and nasal drainage) (33).

Allergens from cockroach, dust mite and mouse urine were not detected in the dust samples at the two hospital buildings. These allergens were probably not a factor in the respiratory health problems at the hospital.

Cat allergen levels in floor dust were positively associated with work-related lower respiratory symptoms but did not remain in the multivariate model. It is common to have cat allergen in public buildings and homes even when cats are not present (10). The cat allergen was probably carried into the hospitals on clothing. There are conflicting data regarding whether high levels are a risk factor or a protective factor for respiratory symptoms (35-37).

Previous research has shown that high levels of airborne latex allergen concentrations, ranging from 14 to 208 ng/m³, are often found in hospital areas where powdered latex gloves are used (38, 39).

Where glove use was minimal, concentrations of less than 2 ng/m³ were found. Where latex gloves were not in use, no airborne latex allergen was detected (40). Airborne latex allergen was not detected in the East or West Campus hospitals.

In a Denver hospital, dust samples from air-handling unit filters from clinical areas had concentrations of latex antigens ranging from 4.43 x 10⁶ ng/mg to 8.37 x 10⁷ ng/mg (41). Dust samples from surface and air-handling unit filters from non-clinical areas were mostly non-detectable. In our study, the highest level of latex allergen in ventilation duct dust was 3.76 x 10² ng/mg, four orders of magnitude lower than in the Denver hospital. In general, latex allergen concentrations at Benefis Healthcare were low. Within Benefis data, the highest ventilation duct latex allergen reservoirs were found in the West Campus hospital Convenience Care West, Surgery, Rehabilitation, and Transitional Care.

McCarthy *et al.* (42) suggests cleaning of high glove use areas may be required after glove conversion to remove reservoirs that may remain such as above ceilings, in and around ductwork, and equipment surfaces. From our data, chairs may also be a reservoir and may need thorough cleaning by HEPA (High Efficiency Particulate Air) filtered vacuuming.

Some of the reported respiratory health effects in this study may have been associated with exposures that we did not evaluate. In an overview of environmental risks present in the hospital setting, McCarthy and Spengler (42) discussed exposure types relevant to health effects. Sensitizing and allergenic agents include histamines, glutaraldehyde, formaldehyde, hexachlorophene, and psyllium laxatives. Quaternary amines sometimes found in cleaning agents have been associated with occupational asthma (43). Several compounds may have strong irritant effects including cleaning or disinfectant agents, solvents, and surgical smoke.

There has been little research in the field of asthma and indoor air quality in non-residential settings. The Institute of Medicine Committee on the Assessment of Asthma and Indoor Air (44)

determined that there is sufficient evidence of an association between the exacerbation of asthma and exposure to fungi and to dampness indicators. The panel stated that there is inadequate evidence to determine whether or not exposures to fungi, endotoxin or bacteria can lead to the development of asthma. In addition, the panel determined that there was sufficient evidence of a causal relationship between exacerbation of asthma and exposures to cat, cockroach and house dust mite allergen and insufficient evidence for rodent allergen exposures. For the development of asthma, sufficient evidence of a causal relationship was determined for house dust mite allergen. There is inadequate or insufficient evidence to determine whether or not an association exists for cat, rodents or cockroach allergen exposures and development of asthma. The panel strongly recommended that more research was needed to elucidate these relationships.

This study contributes to the growing knowledge base in the field of indoor environmental research by showing that there were relationships between work-related asthma symptoms and our indices of exposure to biologicals and particles. The clustering in time and space of sentinel cases of new onset asthma occurred on a contaminated floor after water incursion in the building envelope. Our data imply likely causation of building-related occupational asthma in relation to the bioaerosols associated with water damage. Our modeling results, which focuses on current exposures and current respiratory effects, support exacerbation of asthma of potentially diverse etiologies (including latex) by these indices of microbial exposures.

RECOMMENDATIONS

We recommend the following for this workplace:

1. Disseminate the findings of this report so that employees with respiratory conditions can consult their physicians or the employee health department regarding any need for relocation or environmental intervention at work or at home.

Prognosis for work-related asthma is improved by early recognition and exposure cessation.

2. Conduct medical surveillance for the early detection of work-related respiratory problems, both for appropriate clinical management and to show whether remediations have been effective in preventing new cases.
3. Promptly remediate water incursions and replace all wetted material that can not be dried out in 24 hours. Doing so reduces the potential for microbial amplification.
4. Use containment measures during renovations that keep exposures to construction dusts and the reservoirs of mold and latex that we identified to a minimum.
5. Institute housekeeping practices that keep dust accumulation at a minimum.
6. Repair eroded and damaged casing liners in ventilation systems on the West Campus.
7. HVAC personnel and infection control officers should review air flow maps (Appendix G) to insure that the airflows observed are in compliance with American Institute of Architects (AIA) and American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) guidelines for airflows required.
8. Provide both service and health-care workers with powder-free latex and/or non-latex gloves where appropriate.
9. Clean areas contaminated with latex dust.

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Table 1. Demographics of all 1273 participants^a in the questionnaire survey at Benefis Healthcare.

	East Campus hospital only N (%)	West Campus hospital only N (%)	Both East/West Campus hospitals N (%)	Other ^b N (%)
Gender (Female)	524/623 (84)	127/162 (78)	250/330 (76)	104/113 (92)
Age (Mean \pm SD)	41.8 \pm 11.4	45.0 \pm 9.7	41.6 \pm 10.6	47.0 \pm 10.7
Current Smoker	85/618 (14)	17/164 (10)	40/330 (12)	12/112 (11)
Former Smoker	132/618 (21)	38/164 (23)	82/330 (25)	35/112 (31)
Never Smoker	401/618 (65)	109/164 (66)	208/330 (63)	65/112 (58)
Tenure Years (Mean \pm SD ^c)	10.6 \pm 8.9	13.4 \pm 9.1	10.9 \pm 8.6	12.3 \pm 8.9

^a Across rows, denominators do not sum to the full 1273 participants due to missing data on questions.

^b Other = Skilled Nursing Center, NW Bypass Building, Doctors Plaza, West Hospital Outpatient Surgery Building, NCMPB Building, Spectrum Building, Work at Home, East Hospital Professional Building, Downtown Building

^c SD = Standard Deviation

Table 2. Demographics of 600 participants in 36 departments linked to environmental sampling data.^a

	East Campus hospital only N (%)	West Campus hospital only N (%)	Both East/West Campus hospitals N (%)
(Gender) Female	327/371 (88)	74/89 (83)	114/135 (84)
Age (Mean \pm SD)	41.3 \pm 11.2	44.4 \pm 9.8	41.8 \pm 9.5
Current Smoker	45/368 (12)	7/89 (8)	14/136 (10)
Former Smoker	83/368 (23)	23/89 (26)	36/136 (26)
Never Smoker	240/368 (65)	59/89 (66)	86/136 (63)
Tenure Years (Mean \pm SD ^b)	10.5 \pm 8.8	13.4 \pm 10.2	12.5 \pm 8.9

^a Across rows, denominators do not sum to the full 600 participants due to missing data on questions.

^b SD = Standard Deviation

Table 3. Reported symptoms within the past 4 weeks and 12 months for all 1273 participating employees.^a

Symptoms	In last 4 weeks N (%)	In last 12 months N (%)
<i>Overall symptoms:</i>		
Wheezing	168/1251 (13)	293/1249 (23)
Chest tightness	122/1251 (10)	213/1247 (17)
Shortness of breath	198/1257 (16)	276/1254 (22)
Any chest symptom	287/1250 (23)	419/1247 (34)
Possible asthma based on Venables ^b	191/1242 (15)	N/A ^c
Possible asthma based on Burney ^d	N/A	386/1221 (32)
Nasal symptoms	798/1229 (65)	940/1225 (77)
Sinus symptoms	664/1221 (64)	860/1226 (70)
Throat irritation	228/1242 (18)	447/1238 (36)
Any upper respiratory symptom	886/1223 (72)	1032/1238 (83)
<i>Work-related symptoms:</i>		
Any work-related chest symptom	99/1220 (8)	134/1198 (11)
Possible work-related asthma (Venables ^b)	67/1239 (5)	N/A
Possible work-related asthma (Burney ^c)	N/A	118/1205 (10)
Any work-related upper respiratory symptom	353/1186 (30)	391/1176 (33)

^a Denominators do not equal the full 1273 participants due to missing data on questions

^b 3 or more lower respiratory symptoms from Venables *et al.* (3) asthma questionnaire

^c N/A = Not Applicable

^d Meets symptom-based Burney *et al.* (5) asthma definition

Table 4. Reported symptoms within the past 12 months, possible asthma based on symptom groupings, and physician-diagnosed asthma, by campus for all participating employees (N=1273).^a

Symptoms	East Campus hospital only N (%)	West Campus hospital only N (%)	Both East/West Campus hospitals N (%)	Other N (%)
<i>Overall symptoms:</i>				
Wheezing	148/616 (24)	28/164 (17)	88/333 (26)	25/109 (23)
Chest tightness	90/614 (15)	33/164 (20)	65/331 (20)	24/111 (22)
Shortness of breath	141/617 (23)	33/164 (20)	75/334 (22)	23/112 (21)
Any of the above chest symptom	207/614 (34)	52/164 (32)	119/330 (36)	37/112 (32)
Possible asthma based on Venables ^b	103/613 (17)	18/162 (11)	49/329 (15)	17/111 (15)
Possible asthma based on Burney ^c	194/599 (32)	46/163 (28)	109/327 (33)	33/108 (31)
Nasal symptoms	462/606 (76)	119/159 (75)	260/329 (79)	83/105 (79)
Sinus symptoms	411/605 (68)	107/159 (67)	245/328 (75)	81/108 (75)
Throat irritation	225/610 (37)	46/162 (28)	131/329 (40)	39/109 (36)
Any upper respiratory symptom	505/612 (83)	133/160 (83)	281/330 (85)	93/109 (85)
Physician-diagnosed asthma	111/619 (18)	28/165 (17)	51/333 (15)	22/113 (19)
Physician-diagnosed asthma with post-hire onset	44/608 (7)	9/159 (6)	20/325 (6)	8/110 (7)
<i>Work-related symptoms:</i>				
Any work-related chest symptom*	89/592 (15)	9/160 (6)	31/312 (10)	3/109 (3)
Possible work-related asthma (Venables ^b)*	48/612 (8)	3/161 (2)	12/328 (4)	3/111 (3)
Possible work-related asthma (Burney ^c)*	80/592 (14)	7/161 (4)	25/322 (8)	4/106 (4)
Any work-related upper respiratory symptom*	221/585 (38)	28/152 (18)	109/315 (35)	25/99 (25)

^a Denominators do not equal the full 1273 participants due to missing data on questions

^b 3 or more lower respiratory symptoms from Venables *et al.* (3) asthma questionnaire

^c Meets symptom-based Burney *et al.* (5) asthma definition

* Significant differences between East and West Campus hospital participants (Chi-Square $p < 0.05$)

Table 5. Odds ratios^a (OR) and 95% confidence intervals (CI) for subjective assessment scores, from final multivariate models^b on work-related lower respiratory symptom outcomes.

		Any one or more of work-related wheeze, chest-tightness, or shortness of breath in the last 12 months		Any 3 or more of Venables asthma symptom questions with work-related pattern	
Variable Category	Analysis Variable	OR	(95% CI)	OR	(95% CI)
Environmental Assessment measures	Subjective score category:				
	1 (highest quartile)	2.4	(1.2-4.7)	2.1	(0.9-5.0) (p=0.07)
	2	1.7	(0.9-3.4) (p=0.26)	1.6	(0.5-5.1) (p=0.44)
	3	1.5	(0.7-3.1) (p=0.26)	0.6	(0.2-1.8) (p=0.38)
	4 (lowest quartile)	1		1	
Personal	female gender	---		---	
	age	---		---	
	smoking category	---		---	
	physician-diagnosed asthma	5.0	(3.0-8.2)	4.4	(2.3-8.6)
	physician-diagnosed latex allergy	---		3.4	(1.1-10.5)
Home	Moldy odors in home: Yes vs. No	0.2	(0.07-0.8)	---	
	Water damage in home: Yes vs. No	---		0.2	(0.02-1.2)

^a ORs for environmental assessment measures for which p < 0.10 are shown, and in **bold type** if p < 0.05. For the visual assessment score categories, the p-values are included after the confidence intervals.

^b All models corrected for age, gender, smoking status, and asthmatic status. When effects are not significant at the p < 0.10 level, ORs are not included in the table.

Table 6. Associations between lower respiratory outcomes and environmental measures, using univariate logistic regression.^a

	Any chest symptom in last 12 months	Any work-related chest symptom in last 12 months	Any chest symptom in last 4 weeks	Any work-related chest symptom in last 4 weeks	Venables asthma	Venables asthma with work-related symptoms	Burney asthma	Burney asthma with work-related symptoms
Subjective Score		++		++		++		++
Air VOC category		++		++		++		++
Air ln(endotoxin/m ³)	++	++	++	++	++	++		++
Air geometric mean ultrafine particle count (particles/cm ³)	++	++	++	++	++	++		++
Air mean culturable fungi (CFU/m ³)	++	++	++	++	++	++		++
Air geometric mean spore count (spores/m ³)	++	++	++	++	++	++		++
Chair ln(endotoxin/chair)	++		++					
Chair culturable <i>Pen/Asp</i> (CFU/chair)	+	++	++	++	++	++		++
Chair ln(EPS- <i>Pen/Asp</i> /chair)	++		++					
Chair ln(β 1-3 glucan/chair)	++		++					
Chair ln(latex/chair)	++							
Chair ln(bacteria/chair)			+	++				
Floor mean culturable <i>Cladosporium herbarum</i> /m ²	++							
Floor culturable <i>Alternaria alternata</i> /m ²		+		++				
Floor ln(EPS- <i>Pen/Asp</i> /m ²)		++		++		++		++
Floor ln(β 1-3 glucan/m ²)					+	+		
Floor cat allergen ln(Fel d 1/m ²)		++		++		+		++

++ indicates a positive association at $p < 0.05$, between the health outcome and the environmental assessment measure

+ indicates a positive association at $p < 0.10$, between the health outcome and the environmental assessment measure

^a N = 770 to 794 for the Subjective score analysis, depending on the health outcome. N = 541 to 558 for air sampling data. N = 512 to 527 for chair dust sampling data. N = 365 to 492 for floor dust sampling data.

Table 7. Odds ratios^a (OR) and 95% confidence intervals (CI) for air sampling measures, from final multivariate models^b on lower respiratory symptom outcomes.

Variable Category	Analysis Variable	Any one or more of wheeze, chest-tightness, or shortness of breath in the last 12 months		Any one or more of work-related wheeze, chest-tightness, or shortness of breath in the last 12 months		Any 3 or more of Venables asthma symptom questions		Any 3 or more of Venables asthma symptom questions with work-related pattern	
		OR	(95% CI)	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
Environmental measures	Endotoxin: ln(EU/m ³)	2.5	(1.4-4.6)	---	---	2.5	(1.5-4.4)	---	---
	Ultrafine particles: geometric mean count (per 1000 increase)	---	---	1.5	(1.3-1.7)	---	---	1.3	(1.03-1.6)
	Total spore count category: 4 th quartile vs. 1 st quartile	---	---	---	---	---	---	2.6	(0.9-7.8)
Personal	female gender	---	---	---	---	---	---	0.3	(0.1-0.9)
	age (per 10 years increase)	---	---	---	---	1.4	(1.04-1.8)	---	---
	tenure (per 1 year increase)	1.0	(1.0-1.1)	---	---	---	---	---	---
	smoking current vs never	2.3	(1.2-4.2)	---	---	---	---	---	---
	physician-diagnosed asthma	13.2	(7.2-24.4)	5.1	(2.8-9.3)	7.0	(3.9-12.5)	4.3	(2.0-9.2)
physician-diagnosed latex allergy	2.8	(0.96-8.1)	---	---	3.3	(1.1-9.9)	---	---	
Home	moldy odors in home: Yes vs. No	---	---	0.3	(0.1-1.1)	---	---	---	---
	mold in home: Yes vs No	---	---	---	---	2.0	(0.98-4.2)	---	---

^a ORs for environmental assessment measures for which p < 0.10 are shown, and in **bold type** if p < 0.05.

^b All models corrected for age, gender, smoking status and asthmatic status. When effects are not significant at the p < 0.10 level, the ORs are not included in the table.

Table 8. Odds ratios^a (OR) and 95% confidence intervals (CI) for chair dust sampling measures, from final multivariate models^b on lower respiratory symptom outcomes.

Variable Category	Analysis Variable	Any one or more of wheeze, chest-tightness, or shortness of breath in the last 12 months		Any one or more of work-related wheeze, chest-tightness, or shortness of breath in the last 12 months		Any 3 or more of Venables asthma symptom questions		Any 3 or more of Venables asthma symptom questions with work-related pattern	
		OR	(95% CI)	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
Environmental measures	Latex allergen: ln(ng/chair)	1.2	(1.0-1.4)	---	---	---	---	---	---
	Culturable <i>Penicillium/Aspergillus</i> Present vs Not Present	---	---	2.6	(1.4-4.8)	2.3	(1.2-4.1)	2.6	(1.1-6.2)
Personal	female gender	---	---	---	---	---	---	---	---
	age (per 10 years increase)	1.3	(1.1-1.6)	---	---	1.3	(1.0-1.8)	---	---
	smoking current vs never	2.3	(1.2-4.3)	---	---	---	---	---	---
	physician-diagnosed asthma	14.2	(7.4-27.2)	5.8	(3.2-10.6)	7.1	(3.9-12.8)	5.1	(2.7-11.0)
	physician-diagnosed latex allergy	3.3	(1.1-9.7)	3.2	(0.96-11.0)	4.7	(1.4-15.6)	3.6	(0.8-15.3)
Home	moldy odors in home: Yes vs. No	---	---	0.2	(0.07-0.8)	---	---	---	---
	water damage in home: Yes vs. No	---	---	---	---	---	---	0.2	(0.02-1.3)

^a ORs for environmental assessment measures for which $p < 0.10$ are shown, and in **bold type** if $p < 0.05$.

^b All models corrected for age, gender, smoking status and asthmatic status. When effects are not significant at the $p < 0.10$ level, the ORs are not included in the table.

Table 9. Odds ratios^a (OR) and 95% confidence intervals (CI) for floor dust sampling measures, from final multivariate models^b on lower respiratory symptom outcomes.

Variable Category	Analysis Variable	Any one or more of wheeze, chest-tightness, or shortness of breath in the last 12 months		Any one or more of work-related wheeze, chest-tightness, or shortness of breath in the last 12 months		Any 3 or more of Venables asthma symptom questions		Any 3 or more of Venables asthma symptom questions with work-related pattern	
		OR	(95% CI)	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
Environmental measures	EPS- <i>Pen/Asp</i> : ln(ng EqU/m ²)	---		1.6	(1.2-2.2)	---		1.9	(1.2-3.0)
	β1-3 Glucans: ln(μg/m ²)	---		---		1.4	(0.97-2.0)	---	
Personal	female gender	---	---	---		---		---	
	age (per 10 years increase)	1.4	(1.1-1.8)	---		1.5	(1.0-2.0)	---	
	smoking current vs never	2.4	(1.2-5.1)	2.4	(0.98-6.1)	---		---	
	physician-diagnosed asthma	16.2	(7.4-35.3)	7.9	(3.9-16.1)	11.5	(5.5-24.2)	10.1	(4.0-25.5)
	physician-diagnosed latex allergy	4.2	(1.3-13.9)	3.0	(0.84-11.1)	---		---	
Home	moldy odors in home: Yes vs. No	---		---		3.3	(1.3-8.5)	---	
	water damage in home: Yes vs. No	---		0.2	(0.04-1.0)	---		---	

^a ORs for environmental assessment measures for which p < 0.10 are shown, and in **bold type** if p < 0.05.

^b All models corrected for age, gender, smoking status and asthmatic status. When effects are not significant at the p < 0.10 level, ORs are not included in the table.

Table 10. Associations between upper respiratory outcomes and environmental measures, using univariate logistic regression.^a

	Any upper respiratory symptom in the last 12 months	Any work-related upper respiratory symptom in the last 12 months	Any upper respiratory symptom in the last 4 weeks	Any work-related upper respiratory symptom in the last 4 weeks
Subjective Score		++		
Air ln(endotoxin/m ³)		++		++
Air VOC category		++		++
Air geometric mean ultrafine particle count (particles/cm ³)	++	++		++
Air mean culturable fungi (CFU/m ³)	+	++	+	++
Air geometric mean spores (Spore/m ³)		++		++
Chair culturable <i>Pen/Asp</i> chair (CFU/chair)		++		++
Chair ln(EPS- <i>pen/asp</i> //chair)	+			
Chair ln(latex/chair)				++
Floor culturable <i>Pen/Asp</i> (CFU/m ²)				++
Floor ln(EPS- <i>Pen/Asp</i> /m ²)		++		
Floor <i>C. herbarum</i> /m ²	++			

++ indicates a positive association at $p < 0.05$, between the health outcome and the environmental assessment measure

+ indicates a positive association at $p < 0.10$, between the health outcome and the environmental assessment measure

^a N = 761 to 790 for the subjective score analysis, depending on the health outcome. N = 540 to 559 for air sampling data. N = 508 to 527 for chair dust sampling data. N = 362 to 492 for floor dust sampling data.

Table 11. Odds ratios^a (OR) and 95% confidence intervals (CI) for air sampling measures, from final multivariate models^b on upper respiratory symptom outcomes.

Variable Category	Analysis Variable	Any one or more of nasal, sinus or throat symptoms in the last 12 months		Any one or more of work-related nasal, sinus or throat symptoms in the last 12 months		Any one or more of nasal, sinus or throat symptoms in the last 4 weeks		Any one or more of work-related nasal, sinus or throat symptoms in the last 4 weeks	
		OR	(95% CI)	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
Environmental measures	Ultrafine particles: geometric mean count (per 1000 increase)	---		1.3	(1.2-1.5)	---		1.3	(1.2-1.5)
Personal	female gender	2.6	(1.4-4.9)	---		---		---	
	age (per 10 years increase)	---		---		---		---	
	smoking current vs never	---		---		---		---	
	physician-diagnosed asthma	3.9	(1.2-4.2)	2.1	(1.3-3.4)	3.4	(1.7-7.0)	2.1	(1.2-3.4)
Home	moldy odors in home: Yes vs. No	---		0.5	(0.3-1.0)	---	(1.1-4.8)	0.4	(0.2-0.8)
	water damage in home: Yes vs No	---		---		2.2		---	

^a ORs for environmental assessment measures for which $p < 0.10$ are shown, and in **bold type** if $p < 0.05$.

^b All models corrected for age, gender, smoking status and asthmatic status. When effects are not significant at the $p < 0.10$ level, ORs are not included in the table.

Table 12. Odds ratios^a (OR) and 95% confidence intervals (CI) for chair dust sampling measures, from final multivariate models^b on upper respiratory symptom outcomes.

Variable Category	Analysis Variable	Any one or more of nasal, sinus or throat symptoms in the last 12 months		Any one or more of work-related nasal, sinus or throat symptoms in the last 12 months		Any one or more of nasal, sinus or throat symptoms in the last 4 weeks		Any one or more of work-related nasal, sinus or throat symptoms in the last 4 weeks	
		OR	(95% CI)	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
Environmental measures	EPS- <i>Pen/Asp</i> : ln(ng EqU/chair)	1.4	(0.97-2.0)	---	---	---	---	---	---
	Culturable <i>Penicillium/Aspergillus</i> present vs. not present	---	---	1.6	(1.1-2.4)	---	---	1.7	(1.1-2.6)
	Latex allergen: ln(ng/chair)	---	---	---	---	1.2	(0.98-1.3)	1.2	(1.01-1.4)
Personal	female gender	2.0	(1.0-3.9)	---	---	---	---	---	---
	age (per 10 years increase)	---	---	---	---	---	---	---	---
	smoking current vs never	---	---	---	---	---	---	---	---
	physician-diagnosed asthma	4.1	(1.4-11.8)	2.3	(1.4-3.9)	3.4	(1.7-7.0)	2.3	(1.3-3.8)
	physician-diagnosed latex allergy	---	---	2.9	(1.0-8.2)	---	---	2.6	(0.9-7.5)
Home	moldy odors in home: Yes vs. No	---	---	0.5	(0.2-0.8)	---	---	0.3	(0.2-0.7)
	water damage in home: Yes vs No	---	---	---	---	2.1	(0.99-4.5)	---	---

^a ORs for environmental assessment measures for which $p < 0.10$ are shown, and in **bold type** if $p < 0.05$.

^b All models corrected for age, gender, smoking status and asthmatic status. When effects are not significant at the $p < 0.10$ level, ORs are not included in the table.

Table 13. Odds ratios^a (OR) and 95% confidence intervals (CI) for floor dust sampling measures, from final multivariate models^b on upper respiratory symptom outcomes.

Variable Category	Analysis Variable	Any one or more of nasal, sinus or throat symptoms in the last 12 months		Any one or more of work-related nasal, sinus or throat symptoms in the last 12 months		Any one or more of nasal, sinus or throat symptoms in the last 4 weeks		Any one or more of work-related nasal, sinus or throat symptoms in the last 4 weeks	
		OR	(95% CI)	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
Environmental measures	EPS- <i>Pen/Asp</i> : ln(ng EqU/m ²)	1.4	(0.97-2.0)	---	---	---	---	---	---
	Culturable <i>C. herbarum</i> present vs. not present	---	---	1.6	(1.1-2.4)	---	---	---	---
	Culturable <i>Penicillium/Aspergillus</i> present vs. not present	---	---	---	---	---	---	2.6	(1.5-4.5)
	β1-3glucans: ln(μg/m ²)	---	---	---	---	---	---	1.3	(1.0-1.7)
Personal	female gender	2.0	(1.0-3.9)	---	---	---	---	---	---
	age (per 10 years increase)	---	---	---	---	---	---	---	---
	smoking current vs never	---	---	---	---	---	---	---	---
	physician-diagnosed asthma	4.1	(1.4-11.8)	2.3	(1.4-3.9)	2.9	(1.4-5.8)	2.8	(1.5-5.1)
	physician-diagnosed latex allergy	---	---	2.9	(1.0-8.2)	---	---	---	---
Home	moldy odors in home: Yes vs. No	---	---	0.5	(0.2-0.8)	---	---	0.3	(0.1-0.8)
	water damage in home: Yes vs No	---	---	---	---	2.3	(1.0-5.0)	---	---

^a ORs for environmental assessment measures for which p < 0.10 are shown, and in **bold type** if p < 0.05.

^b All models corrected for age, gender, smoking status and asthmatic status. When effects are not significant at the p < 0.10 level, ORs are not included in the table.

Figure 1. Distribution of lower respiratory symptoms, symptom-based possible asthma, and physician-diagnosed asthma across the floors of the East (E) and West (W) Campus hospitals.

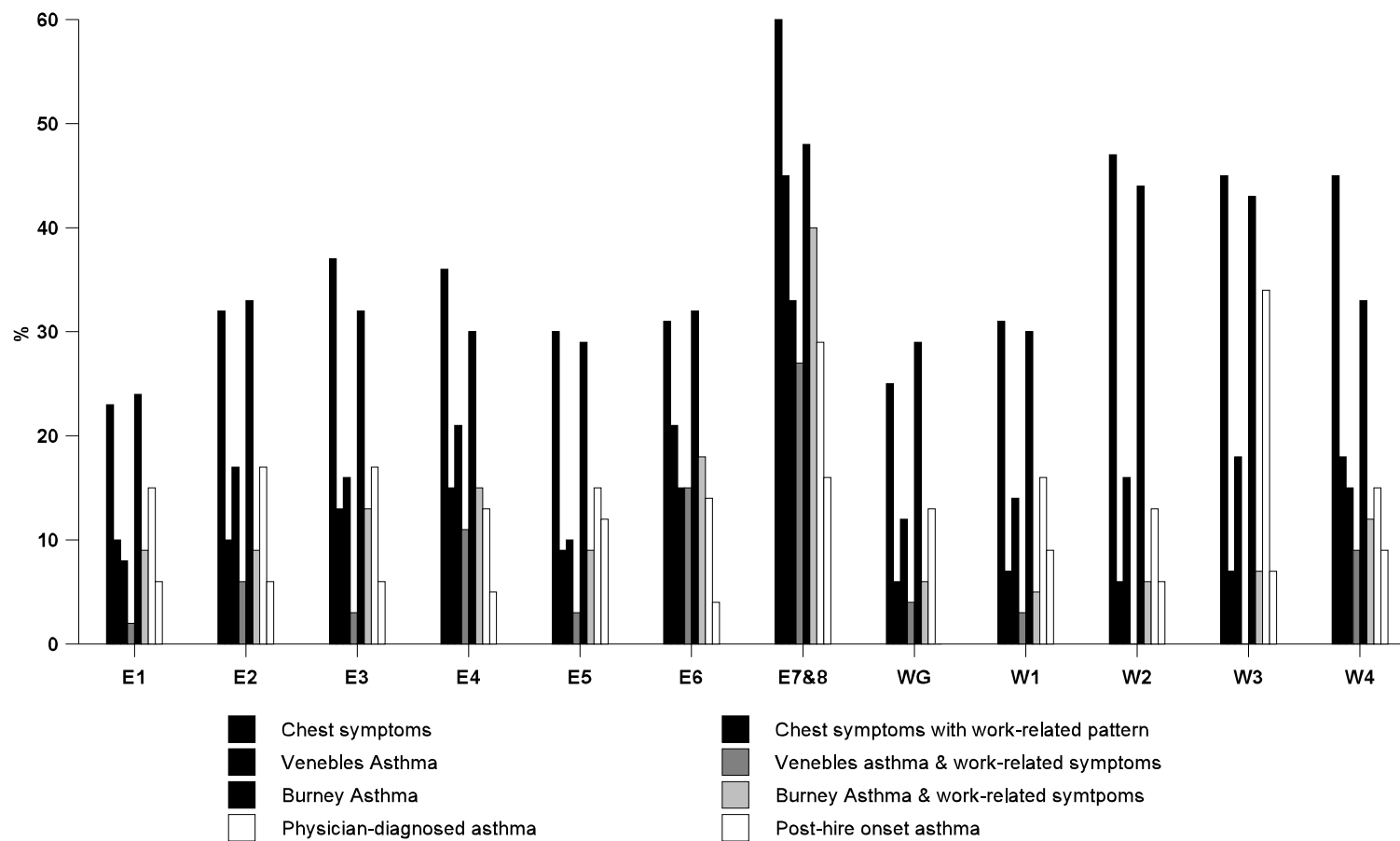


Figure 2. Distribution of upper respiratory symptoms across the floors of the East (E) and West (W) Campus hospitals

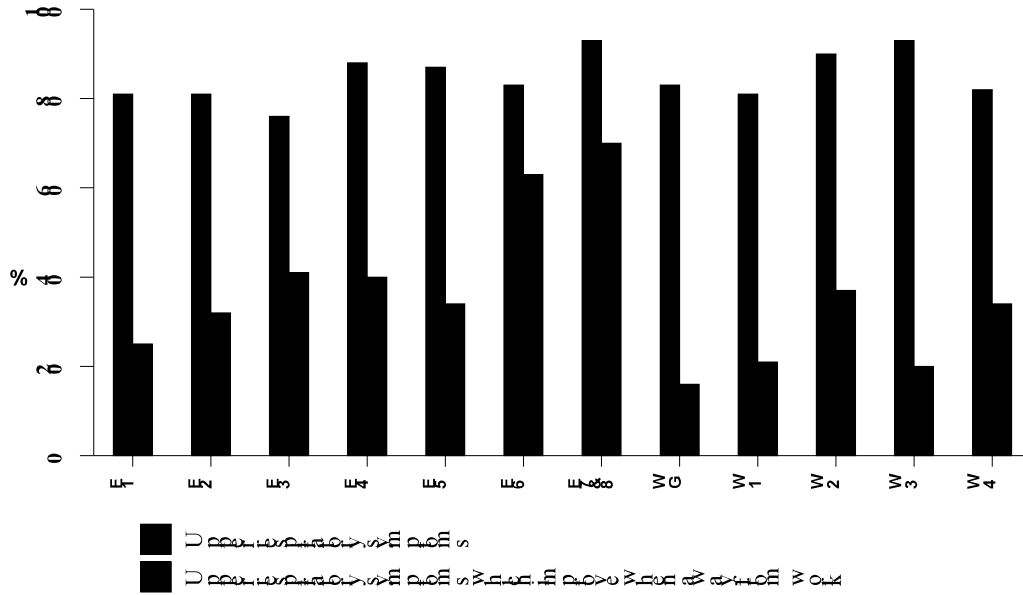
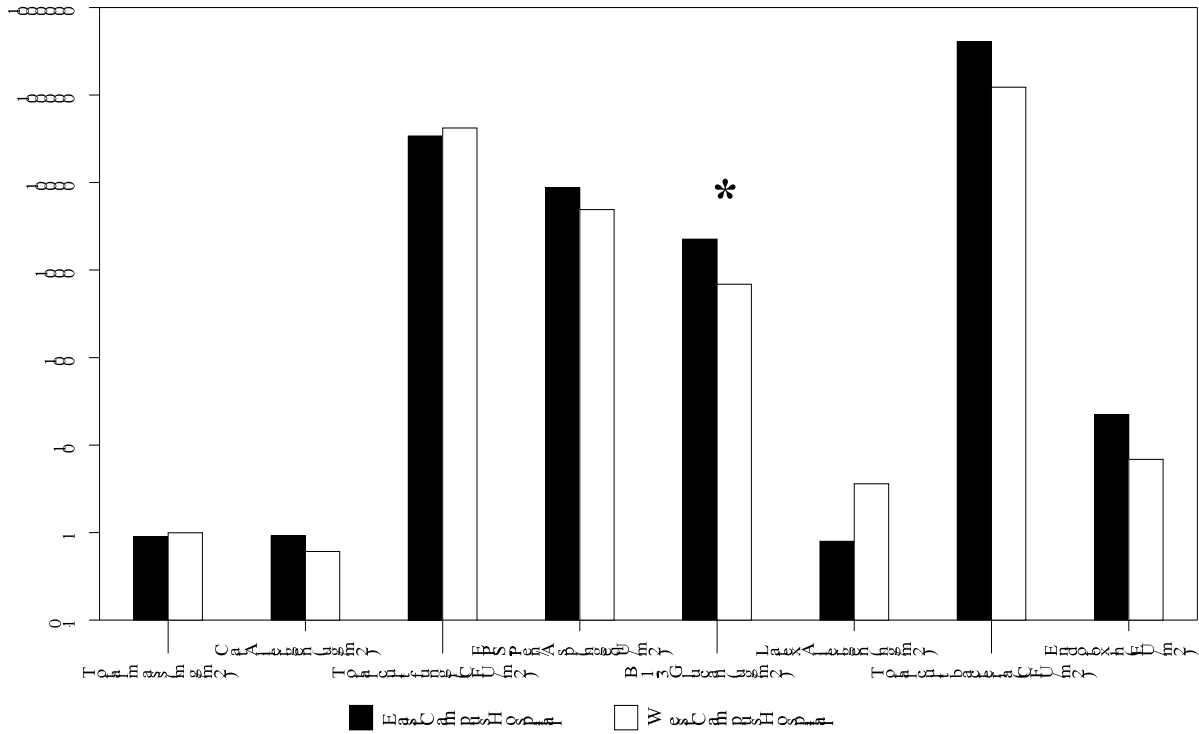
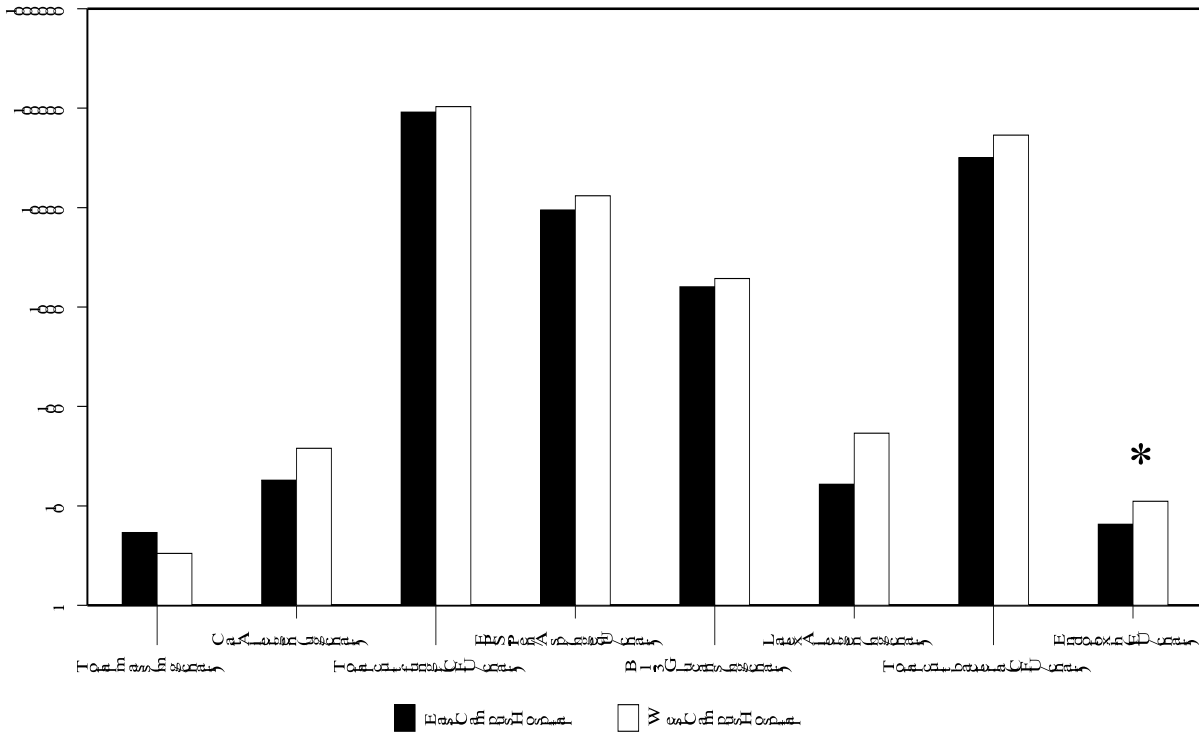


Figure 3: Comparison of the geometric means of environmental analytes in floor dust at the East and West Campuses (Note: Concentration units for each analyte are listed on the x-axis)



* East and West Campus hospitals significantly different ($p < 0.05$)

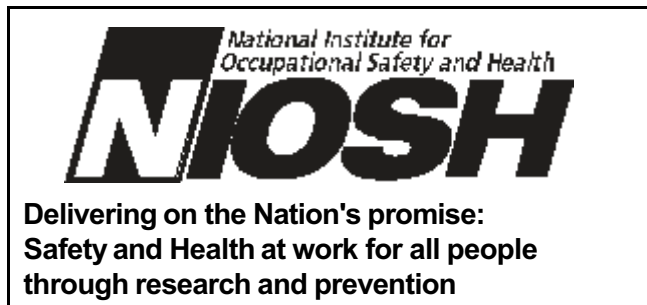
Figure 4: Comparison of the geometric means of environmental analytes in chair dust at the East and West Campuses (Note: Concentration units for each analyte are listed on the x-axis)



* East and West Campus hospitals significantly different ($p < 0.05$)

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