levels of 5-15 ppm may not be economically feasible.... Our results showed that maintaining a DBNPA concentration of 1 ppm achieved the same magnitude of reduction in *Legionella* ... with the added advantage of continuous control. These results suggest that DBNPA (98% active powder) is a viable option for the control of *Legionella* in industrial cooling systems."

The American Society of Heating, Refrigerating and Air-Conditioning Engineers states in its document *Risk of Legionellosis Associated with Building Water Systems* that there are four objectives in treating cooling water systems:

1. Minimize microbial growth
2. Minimize scale
3. Minimize corrosion
4. Minimize sediment and deposition of solids on heat-transfer surfaces

Gao, Lin, Stout, Vidic, and Zhou recommend that researchers conduct field tests to "document the efficacy of continuous or semicontinuous low-level dosing of DBNPA (as 98% active powder)."

For more information, contact Janet Stout, director, Special Pathogens Laboratory, Infectious Disease Section, Veterans Administration Healthcare Center, University Drive C, Pittsburgh, PA 15240. Tel: (412) 688-6000, ext. 4701; Fax (412) 683-6928; E-mail: jes20+@pitt.edu.

[*Editor's note:* Gao, Lin, Stout, Vidic, and Zhou report that their work was partly sponsored by Clearon Corporation of New Jersey, which is a subsidiary of Dead Sea Bromine Group of Beer-Sheva, Israel. Clearon and its parent produce the 98% active powder DBNPA that the researchers tested. The eight-page Material Safety Data Sheet (MSDS, code: 8341L) on DBNPA, which the parent company sells under the product name, Biobrom C-103L, states that the adverse health effects of 2,2-dibromo-3-Nitrilopropionamide are that it is a "severe irritant" and is harmful if inhaled or swallowed. The MSDS states that DBNPA also poses a risk of serious eye damage and "may cause sensitization by skin contact." The product is stable under "normal conditions," is not mutagenic by the Ames Test, and is not a known carcinogen. For additional information, including handling instructions, see the MSDS for Biobrom C-103 at www.deadseabromine.com.]

CASE STUDY

[In each issue, **IEQS** *presents a case study on an indoor air investigation in a particular building. The information in the cases comes from various sources, including published material, reports in the public record, and, in some cases, reports supplied by the consultants involved in the case.* **IEQS** *presents a variety of approaches to investigation and mitigation implemented by consultants with a broad range of experience, philosophies, and expertise. Inclusion of a particular case study in the newsletter does not imply* **IEQS***'s endorsement of the investigative procedures, analysis, or mitigation techniques employed in the case.* **IEQS** *invites readers to submit comments, suggestions, and questions concerning the case. At the discretion of the editors, correspondence may be presented in a future issue.]*

Renovating a Mold-Contaminated Facility That Serves Cancer Outpatients

In November 1997, a contractor asked the US National Institute for Occupational Safety and Health (NIOSH) to perform a health hazard evaluation at a facility for pediatric cancer outpatients in the US Southeast. The contractor was concerned because his employees became ill after they renovated fungal-contaminated building materials at the facility. Their symptoms included diarrhea, stomach cramps, vomiting, dizziness, weakness, and fatigue. The NIOSH team's initial sampling indicated an immediate need for microbial remediation, according to Angela Weber and Elena Page, who wrote about the case study in the January 2001 issue of *Applied Occupational and Environmental Hygiene*, a peer-reviewed journal published by the American Conference of Governmental Industrial Hygienists. Weber is an industrial hygienist, and Page is an occupational health physician. Both work at the Division of Surveillance, Hazard Evaluations and Field Studies for NIOSH.

The 5,000 square foot (ft^2) facility was affiliated with a university hospital and served as housing for outpatients and their parents who lived more than

50 miles away. The original two-story building was constructed in 1961 and expanded in 1985, 1991, and 1993. In addition to 18 guestrooms and the resident manager's apartment, the building contained four suites for children who had received bone marrow transplants, offices, common areas, and other rooms. Through-wall heat pump systems ventilated the transplant suites and all but two guestrooms. Five central heat pump units served the remainder of the facility. These central units received return air through a common ceiling plenum.

Six employees worked 20- to 40-hour weeks at the facility, and the resident manager lived there with her family. One additional employee worked there about 10 hours a week, and eight others worked there every eighth weekend.

History of Water Damage

According to managers, the building had sustained moisture problems since 1986. Water permeated the exterior walls, leaked through the roof, and drained improperly from the through-wall heat pump units. A flood in May 1993 caused major damage to both floors. Managers reported "musty odors" in the building dating back at least that long. Most Sheetrock and ceiling tiles were not replaced after the flood. The university's Occupational and Environmental Safety Office reported it had found elevated concentrations of *Penicillium* in the lobby in 1995. At the time, they thought it was due to condensation and moisture around a chimney. They also uncovered moisture problems related to the through-wall heat pumps and elevated concentrations of Gram-negative bacteria in the unit drain pans — an indication of high moisture content. In addition, water seeped in through the foundation due to poor drainage, and the building lacked vapor barriers. The resulting water intrusion rusted electrical boxes.

Renovations included new flooring throughout the building and removing, cleaning, and reinstalling the through-wall heating units to stop further improper drainage into the wall cavity. Of 16 carpeted areas to be replaced, all but two were wet beneath the through-wall units.

The contracting crew that performed most of the work had no training in handling contaminated building materials. They wore no respirators or other protective equipment and did not erect barriers to isolate the renovated rooms. Less than three weeks into the job, the contract employees became ill and grew concerned that their symptoms were due to their exposure to contaminated building materials. The university collected an air sample that grew more than 2,628 colony forming units per cubic meter (cfu/m^3). The exact concentration was unknown because the culture plate became overgrown with fungi. The sample included *Cladosporium*, *Penicillium*, and other unspeciated fungi. About two weeks before visiting the site, NIOSH recommended that the renovations cease until someone established proper environmental controls.

NIOSH Investigation

During its initial visit, the NIOSH team interviewed the five renovation employees, reviewed their medical records, and interviewed the seven employees who worked full time at the facility. Team members also visually inspected the building and subsequently returned to collect air samples to determine the species present and the concentration of airborne spores. They used Greasley/Anderson 2-stage viable cascade impactors calibrated at a flow rate of 28.3 liters per minute (l/min) for a period of 10 minutes to determine the concentrations of culturable airborne fungi. Over two days, they collected 100 air samples in 17 indoor locations and 19 air samples in three outdoor areas and recorded the indoor temperature and relative humidity at each location. They used malt extract agar (MEA) to culture for hydrophilic fungi and corn meal agar to look for *Stachybotrys chartarum*. They collected an additional sample at each site on MEA to test for thermo-tolerant fungi including *Aspergillus fumigatus*. *Aspergillus fumigatus* and *Aspergillus flavus* were a concern because they can cause an opportunistic infection, aspergillosis, at very low concentrations in people at risk such as the young patients housed at this facility. Invasive aspergillosis is a serious infection that can prove fatal; it tends to strike patients with weakened immune systems (such as leukemia or lymphoma patients).

The NIOSH team also collected 4 settled-dust, 4 cello-tape, and 9 bulk samples from visibly contaminated building materials. From its samples, the NIOSH team hoped to:

- Determine if the renovations had disseminated spores

- Evaluate if fungi were adequately removed from renovated areas
- Determine background concentrations and species of mold in rooms scheduled for remediation

Medical Evaluation Results

One of the seven full-time employees at the facility had suffered from afternoon headaches for several years that resolved each day after the employee left work. No other full-time employee had any work-related health complaints. The live-in manager's two children have allergic rhinitis, and both reported that this condition increased briefly during the renovations.

The five contract employees who removed the moldy Sheetrock reported symptoms that were possibly related to their exposure to the contamination. The primary routes of exposure would be through inhalation and skin contact. The most common symptoms among four of these employees, however, were diarrhea and vomiting, with the first episode beginning 2-3 weeks after they arrived at the facility. None reported any respiratory or skin symptoms. It is unusual for fungal infections or mycotoxicoses to cause gastrointestinal illness in several otherwise healthy persons, and their medical records did not suggest either as the cause. Conversely, the employees reported that they worked closely and ate together, and there was evidence of infectious (bacterial) gastroenteritis in one contract employee.

Sampling Results

The team's 19 outdoor air samples revealed total fungal concentrations ranging from 92-1,004 cfu/m^3 with the average being 312 cfu/m^3. *Cladosporium* dominated 18 of the 19 samples and, overall, composed 74% of total colonies. *Penicillium* comprised 5% of the outdoor isolates. During sampling, outdoor temperatures ranged from 46°F-60°F, and relative humidity (RH) ranged from 27%-35%.

The 100 indoor samples the investigators collected had an average of 147 cfu/m^3 with a range from 25 cfu/m^3 to "too numerous to count" (more than 400 cfu/m^3). The average concentration in remediated areas was 196 cfu/m^3 versus 126 cfu/m^3 in non-remediated areas. *Cladosporium* dominated 45% of indoor samples versus 95% of outdoor samples, while *Basidiomycetes* dominated 40% of indoor samples versus 5% of outdoor samples. *Penicillium* accounted for 5% of outdoor versus 15% of indoor samples, and *Memnoniella echinata*, which was not detected outside, dominated samples collected in the playroom, dining room, and a guestroom, and was also detected in three other guestrooms. They also found *Aspergillus versicolor* in all sample locations in the building. In all, they recovered 7 species of *Aspergillus* indoors that they did not find in outdoor samples. Indoor temperatures ranged from 64°F-78°F, and the RH ranged from 18%-51% during the sampling period.

Regarding sampling for thermo-tolerant fungi, outdoor concentrations ranged from none detected to 35 cfu/m^3 with an average concentration of 13 cfu/m^3. They found *Aspergillus fumigatus* in 7 of the 10 outdoor samples versus the playroom and two transplant suites indoors. They also found *Aspergillus niger*, *Aspergillus nidulans*, *Paecilomyces variotii*, *Mucor*, *Penicillium*, and sterile thermo-tolerant fungi.

Air samples for total spore concentrations throughout the outpatient facility ranged from none detected to 160,825 spores/m^3 collected in a guestroom. The average spore concentration indoors of 13,333 spores/m^3 approximate the outdoor average (10,519 spores/m^3). These included spores from *Cladosporium*, *Aspergillus*, *Penicillium*, and *Stachybotrys*.

Bulk samples yielded a range from undetectable levels of mold to 14.1 million cfu/g. The latter was in a transplant suite where the investigators found that *Acremonium* and *Stachybotrys chartarum* dominated the wet paper backing behind a bathroom baseboard. They also found that visually contaminated materials related to through-wall heat pump leaks harbored *Memnoniella echinata*, *Paecilomyces variotii*, *Aspergillus ustus*, *Acremonium*, and *Stachybotrys*. They identified *Rhodotorula* in a guestroom and *Cladosporium*, *Pènicillium*, and *Aspergillus versicolor* on wet insulation in the kitchen, a bathroom, and the laundry room.

Dust samples from through-wall heat pump filters in two transplant suites contained between 2.0 million and 5.96 million cfu/g. *Cladosporium* and

Penicillium dominated these colonies, and the presence of *Rhodotorula, Trichoderma koningii*, and *Paecilomyces variotii* indicated these filters had been chronically wet. When they found *Aspergillus fumigatus* predominated the thermo-tolerant microbes in dust from the return-air side of through-wall ventilation filters in two transplant suites (77% and 62% of cfu, respectively), NIOSH team members knew this indicated that this fungus was probably airborne in these suites at some point. In addition, a variety of mold spores in settled dust collected from the return-air plenum above two guestrooms revealed that the earlier remediation conducted without isolation barriers had probably dispersed spores throughout the heating, ventilation, and air conditioning system.

Finally, 5 tape samples the team had collected from visible fungal growth from a variety of surfaces in the mechanical closet serving the resident manager's apartment all yielded many fungal spores. Hyphae and conidiophores from *Cladosporium herbarum* and *Cladosporium cladosporides* suggested active fungal growth.

Discussion

Generally, the indoor and outdoor airborne mold species that a consultant collects at a given location should be similar. When certain species such as toxigenic *Aspergillus* or *Stachybotrys* predominate indoors but not outdoors nor at indoor control locations, this suggests a moisture problem and that indoor reservoirs exist for the predominating species. The team found that average air concentrations of culturable indoor mold were "considerably lower than those found outdoors," yet the types of indoor species did not mimic their outdoor counterparts. As noted earlier, for example, *Penicillium* species comprised 15% of indoor species collected versus 5% outdoors, and they found 5 species of *Penicillium* and 7 species of *Aspergillus* indoors that it did not find outdoors. Likewise, the team found *Stachybotrys* in six nonremediated indoor locations but did not find it outdoors.

Team members were concerned about the presence of *Aspergillus fumigatus* and other aspergillosis-causing species. In fact, virtually any fungus can become an opportunistic pathogen in patients with compromised immune systems, which was the case for the young patients at this facility. Experts have recommended that airborne concentrations of *Aspergillus* species be kept at or below 0.1 cfu/m^3 to prevent the illness in susceptible patients. At this facility, however, the team recovered average airborne concentrations of *Aspergillus fumigatus* of 4 cfu/m^3 in one transplant suite and 1 cfu/m^3 in another and noted that the patient playroom had the highest average concentration, 5 cfu/m^3. Also as noted, *Aspergillus fumigatus* was the predominant thermo-tolerant microbe found in the dust from the return air filters in the through-wall heating units.

Team members were not able to determine why the remediated areas had a higher average concentration of airborne fungi (196 cfu/m^3) than the non-remediated areas (126 cfu/m^3). They were told, however, that there had been larger amounts of visible mold growth on the ground floor where most of the remediation had occurred. Nobody had measured the background levels of fungi before the renovations. Beyond that, the moisture problems persisted and were worst on the ground floor.

Conclusions

First, the team determined it was unlikely that the contract workers' illnesses were linked to fungi, mycotoxins, or other workplace exposures. Their lack of respirators and other protective clothing, however, did put them at risk for fungal-caused illness. Second, the immunocompromised children who stayed in the transplant suites may have been exposed to hazardous concentrations of *Aspergillus fumigatus*, which can cause aspergillosis. Third, a variety of leaks through the roof and walls, due to improper drainage of through-wall heat pump units, produced ideal conditions for fungal growth. Bulk samples had, in fact, revealed potential reservoir sites for fungal growth throughout the building. Fourth, the lack of isolation of portions of the building during remediation apparently contributed to the spread of spores through the ceiling return-air plenum. Finally, fungal growth on new building materials is likely because of the leaks and the continuing mold contamination.

Recommendations

The team made the following recommendations to stop continuing microbial contamination and ensure proper mold remediation in the building:

1. Repair all leaks and other sources of moisture incursion. Hire a firm that specializes in building design and construction to ensure that

contracting crews correct the architectural flaws including the lack of an exterior-wall vapor barrier.

2. Any remediation of contaminated building materials should follow appropriate abatement protocols.

3. Remediation personnel should wear proper protective equipment including (full-face) HEPA-filtered respirators, clothing, and gloves.

4. Nobody except the abatement team should be in the building during remediation, and the heating units should be shut off. All other heat pumps should be inspected for microbial contamination. "The microbially contaminated fiberglass sound liner … in the central heat pump … should be … replaced, preferably with a smooth-surfaced insulation to prevent the collection of microbial contaminants." After this liner is removed, "all surfaces … should be dried and cleaned with a HEPA-filtered vacuum … before removal."

5. After removing all debris, all heat pump components should be cleaned with a 10% bleach solution and rinsed with water by workers wearing protective equipment.

6. Keep condensate drip pans in the through-wall heat units free of standing water and microbial growth. The drip pans, the unit coils, and drains should be inspected monthly and cleaned as needed.

7. Because of the immunocompromised patients, the hospital, in consultation with the heat pump manufacturer, should seriously consider increasing the filter efficiency of the heating systems. All systems should be checked for gaps around filters.

8. With the heat pump manufacturer's input, facility managers should implement a written preventive maintenance schedule for all heating units. Managers should require that this maintenance be documented and should establish a central file for each heating unit that contains its specifications, design drawings, operational parameters, and other information needed to ensure continuity between mechanical personnel.

9. Air intakes should not be near soil or organic debris that serve as fungal and bacterial reservoirs. "Ideally … the air intake should be moved … at least 25 feet from external bioaerosol amplification sites."

10. Since moisture problems are likely to recur due to built-in architectural flaws, managers should consider relocating all transplant suites to the main floor, where moisture is less of a problem.

11. After remediation, perform air and surface sampling to determine if indoor moisture and microbes are appropriately reduced. This should include comparing indoor samples with outdoor samples and also with samples from an indoor control location. The contractor should collect multiple samples at each location to guard against "sampling variability."

For more information, contact Angela Weber by e-mail at amw1@cdc.gov. More detailed information is also available in Health Hazard Evaluation Report No. 98-0026-2745 available from NIOSH, Hazard Evaluation and Technical Assistance Branch, 4676 Columbia Parkway, Cincinnati, OH 45226. Tel: (800) 356-4674; Fax: (513) 533-8573.

NEWS, ANALYSIS, AND UPDATES

Rat Study Finds "Clear Evidence" That Naphthalene Causes Cancer

You may want to avoid breathing the restroom deodorizers at work, school, hotels, restaurants, and most other large buildings. You may also want to stop using mothballs and moth flakes. Why?

Following a two-year study, the US National Toxicology Program (NTP) has found "clear evidence" that naphthalene ($C_{10}H_8$) — the principal chemical that gives restroom deodorizers and mothballs their somewhat acrid odor — triggers the growth of malignant tumors in rats. Researchers concluded this after the study showed a dose-related increase of malignancies. None of the rats in the control group that was not exposed to naphthalene