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ABATEMENT OF ASPERGILLUS NIGER CONTAMINATION IN A LIBRARY

E.N. Light, CIH **J.A. Coco, CIH** **A.C. Bennett** **K.L. Long**

ABSTRACT

This case study documents a systematic attempt to locate and abate mold growth in a library that had been subject to a series of major roof leaks with employees complaining of building-related allergies. Work was completed in the following sequence: (1) exposure assessment, (2) evaluation of initial corrective measures, (3) identification of residual sources, (4) development of abatement specifications, (5) abatement monitoring, and (6) clearance sampling. Initial air samples revealed high fungal concentrations dominated by the mold, Aspergillus niger, *a sensitizer and opportunistic pathogen. Maintenance personnel subsequently conducted a typical mold/mildew clean-up including elimination of visible mold growth and disinfection of some surfaces. Retesting indicated that* Aspergillus niger *continued to dominate fungal air samples. Specialized cleaning contractor equipment was retained to complete the abatement program. After cleaning with a higher-efficiency vacuum cleaner,* all *surfaces were disinfected. Also, porous, contaminated materials were discarded and the HVAC system was cleaned. Air monitoring was conducted at strategic locations during the project to document mold counts in adjacent occupied areas. Final clearance of the work area was based on completion of abatement specifications which included all surfaces passing visual inspection and airborne fungal counts being less than outside with* Aspergillus niger *not dominating. These criteria were met within two weeks after completion of the clean-up. One year later, airborne fungal concentrations remained in the background range.*

INTRODUCTION

Although microbial contamination can be a major source of building-related illness, there is little guidance available to building managers for remediation. As a result, most attempts to address microbial contamination proceed with a "trial and error" approach.

Microbial evaluation remains one of the least precise areas of indoor air quality assessment. A variety of common environmental fungi and bacteria may be isolated from indoor air samples, with no clear distinction between background and "problem" concentrations (ACGIH 1987). Where unsanitary conditions develop in either mechanical equipment or interior surfaces, microbial growth can be amplified to the point where complaints by allergy-prone individuals become prevalent or more serious building-related illnesses occur (Burge 1988; Morey 1988). The most frequent complaints in buildings with relatively high airborne microbial concentrations generally involve allergic reactions. In relatively rare cases, severe sensitization can be induced in some individuals, resulting in conditions such as hypersensitivity pneumonitis. Elevated levels of some common environmental organisms may also cause infection in immunocompromised individuals. Microbial organisms that can be the source of such infections are known as opportunistic pathogens (Burge 1987; Burge 1988). General approaches for remediating microbial contamination presented in the literature include disinfecting, HEPA vacuum cleaning, discarding contaminated porous material, eliminating moisture sources, and lowering relative humidity (USDA 1980; Morey 1984).

This case study documents a systematic attempt to assess and control a large-scale mold growth problem in a library. The authors were retained as consultants to the facility—first to assess indoor air quality complaints and subsequently, to direct remediation. Present standards for the abatement of asbestos-containing materials were used as guidance in the establishment of work specifications. These were modified substantially to reflect unique aspects of microbial contamination.

The library under investigation is located in the Washington, DC, metropolitan area and is part of a 20-year-old educational facility of 160,000 ft² (14,857 m²). Of primary concern were the library and adjacent offices, which shared a common air handler. For purposes of this project, the space was subdivided into three zones (see Figure 1) as follows:

Zone 1: Library main room (approximately 5000 ft² (464 m²) and site of the most direct water damage).
Zone 2: Six library rooms adjacent to the main room (approximately 2000 ft, 186 m²).
Zone 3: Sixteen offices adjacent to Zone 2 (approximately 5000 ft², 464 m²).

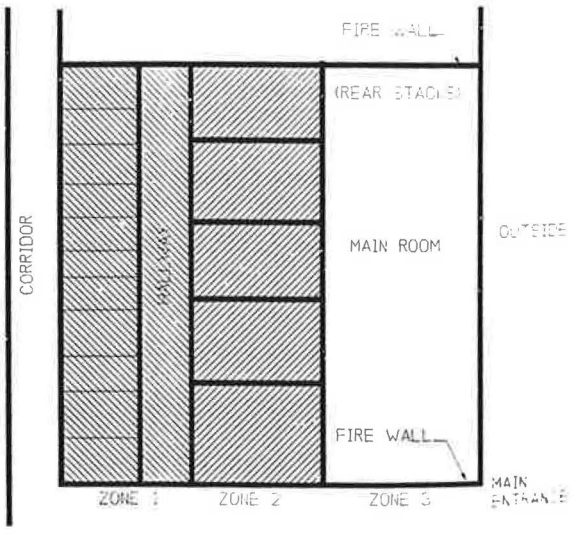

Figure 1 *Library abatement project*

E.N. Light, CIH, is Manager, Indoor Air Quality; **A.C. Bennett, MPH**, is Staff Environmental Scientist, Dames & Moore, Bethesda, MD; **K.L. Long** is Industrial Hygiene Technologist, Biospherics, Inc., Beltsville, MD; **J.A. Coco, CIH**, is Director, Environmental Hygiene Services, Applied Environmental Health and Safety, Inc., Reston, VA.

The sequence of events covered by this case study includes (in chronological order):

1. A series of major roof leaks occur in the library over a two-year period (until effective repairs are implemented).
2. Librarians complain of building-related illness.
3. Authors conduct microbial assessment.
4. In-house clean-up fails to eliminate complaints.
5. Detailed abatement process is designed by authors.
6. Remediation is conducted by an institutional cleaning contractor under supervision of authors.
7. Library meets clearance criteria and is reoccupied.
8. Testing is conducted one year later to determine long-term effectiveness.

METHODOLOGY

Assessment Strategy

Microbial sampling was preceded by a visual inspection of Zones 1 and 2, a limited scope evaluation of the HVAC system, interviews with operational staff, and a review of health questionnaires completed by librarians. Based on these preliminary findings, a sampling scheme was designed to provide a general characterization of airborne microbial concentrations and potential sources.

Initial Remediation

In-house maintenance personnel implemented typical building procedures for dealing with water incursion and subsequent mold growth. Initial efforts involved general cleaning of the affected area and repair of the roof. Employee complaints prompted further efforts, beginning with the authors' microbial assessment. While laboratory results were pending, facility management proceeded with a general mold/mildew clean-up of the area. This was accomplished by in-house maintenance and housekeeping personnel, with no special expertise involved in the effort. This work was restricted to surfaces within Zone 1 with visible growth. Specific actions included:

1. Removing mold stains on walls with a bleach cleaner.
2. Discarding moldy books.
3. Shampooing carpet with a disinfectant.
4. Damp-wiping some shelves and walls.
5. Installing a dehumidifier.

A reassessment of the library following completion of this work provided an evaluation of the effectiveness of a typical maintenance response to a building mold contamination problem. This, in effect, became a control for later comparison with the results of a more systematic abatement approach in the same area.

Abatement Strategy

Detailed specifications for abatement can be found in the appendix. Site-specific requirements were included for Zones 1, 2, and 3 HVAC equipment. Work was sequenced to minimize the recontamination of cleaned areas.

Containment involved sealing entries to adjacent areas with plastic. Cleaning utilized a higher efficiency vacuum cleaner (97% effective for the collection of 0.5 micron particles) followed by disinfection with a substituted phenolic solution (minimum contact time, 20 minutes). Porous materials considered to be contaminated were discarded to ensure that reservoirs of mold spores would not remain after cleaning. Air handlers and ductwork were treated as potential secondary sources of mold contamination. These were cleaned and disinfected to the extent that practical access was available. In addition, encapsulant was applied to insulation in the air handlers and diffuser boxes.

Monitoring Strategy

Abatement work was performed under the supervision of an industrial hygienist who was present during part of each shift to ensure that specifications were followed and to monitor microbial levels. Inspection duties included ensuring that dust was contained and that all porous contaminated materials were removed. Microbial sampling was limited to fungal counts only. Air sampling sites were located in corridors and offices adjacent to abatement areas to evaluate the effectiveness of containment precautions. Representative surface samples were collected in each area to determine the effectiveness of cleaning and containment. Immediately preceding abatement, baseline air and surface samples were collected as a reference to compare any changes documented during the abatement process.

Completion of the cleaning contractor's obligation and reoccupancy of the affected area was to be based on a formal clearance process similar to that used for asbestos abatement (US EPA 1985). Before final air sampling was permitted, the following criteria had to be met:

1. All abatement specifications were successfully completed.
2. All surfaces passed visual inspection.
3. Swabs of representative surfaces did not exceed background fungal concentration. Note: Lacking any guidelines for this parameter, the authors included 1000 CFU/in^2 in the performance criteria for this project to demonstrate that surfaces had been disinfected. Clean building surfaces are typically less than 1000 CFU/in^2 while swab samples in excess of this amount may be considered unsanitary or indicative of sources contributing to airborne microbial problems.

Airborne fungal samples were then collected at representative sites in the abatement areas along with a control outside the building.

Clearance generally required inside fungal concentrations to be less than outside. However, if the outside concentration was low on the day of sampling (less than 500 CFU/m^3), inside fungal counts would be allowed up to 500 CFU/m^3. Finally, *Aspergillus niger* could not dominate any of the samples in order for the work area to be cleared for reoccupancy.

Sampling and Analysis

All microbial sampling, along with subsequent counts and identification of organisms, generally followed standard methods (ACGIH 1987). The initial assessment phase also included systematic documentation of environmental conditions potentially related in microbial growth.

Air samples were collected with a single stage (N-6) viable impactor using Standard Methods Agar media for bacteria and Sabouraud Dextrose Agar for fungi in conjunction with a high-volume air sampling pump. Surface samples were collected with a sterile swab applied to a 2 in by 2 in area. Bulk samples (i.e., carpet) were collected with a sterile cutting tool.

All culture plates obtained from air sampling or the extraction of surface or bulk samples were incubated (3–7 days at 25°C for fungi or 2–3 days at 35°C for bacteria) and then colonies were counted. Taxa were identified in selected sam-

TABLE 1

Initial Assessment — Microbial Sampling Results

Location	Bacteria CFU/m³	Bacteria Type	Fungi CFU/m³	Fungi Type
(Air Samples)				
Zone 1	18	Bacillus sp. Corynebacterium sp.	1382	*Aspergillus niger* Aspergillus sp. Rhizomucor sp. Penicillium sp.
Zone 2 (Room A)	25	Bacillus sp. Corynebacterium sp.	654	*Aspergillus niger* Aspergillus sp. Penicillium sp.
Zone 2 (Room B)	231	Bacillus sp. Micrococcus sp. *Staph. epidermidis* Pseudomonas sp. Flavobacterium sp. Corynebacterium sp.	1026	*Aspergillus niger* Aspergillus sp. Pencillium sp.
(Surface Sample)				
			CFU/in²	Type
Zone 1 – Book			3.5×10^5	*Aspergillus niger* Aspergillus sp.

TABLE 2

Second Assessment — Fungal Sampling Results

Location	Airborne Fungi (CFU/m³)	Fungal Types
Zone 1 (rear)	85	*Aspergillus niger*
Zone 1 (front)	46	*Aspergillus niger*
Zone 1 (ceiling plenum)	71	*Aspergillus niger*
Zone 2 (Room B)	42	*Aspergillus niger*
Zone 3	83	*Aspergillus niger*
Adjacent Corridor (A)	165	Pencillium sp.
	Surface Fungi (CFU/in²)	
Zone 1 Bookshelf (clean)	8	Aspergillus sp.
Zone 1 Bookshelf (not clean)	4	*Aspergillus niger*
	Bulk Fungi (CFU/gm)	
Zone 1 (carpet)	5.6×10^4	*Aspergillus sp.*
Zone 2 (drape)	5.9×10^3	*Aspergillus sp.*

ples using standard medical microbiological isolation and characterization techniques.

RESULTS

Initial Assessment

Health questionnaires completed by the three employees permanently stationed in the library noted several symptoms that seemed to be occurring frequently at work in apparent association with the water leak problem. The symptoms, which were said to diminish upon leaving the building, included asthmatic attacks, sneezing, congestion, swelling, upper respiratory irritation, fatigue, and headaches. Although such symptoms are considered non-specific, they are generally consistent with the response of allergy-prone individuals to elevated levels of sensitizing molds. Personal physicians were said to suspect reported mold exposure in the work place as being responsible for the symptoms. No other significant emission sources or contaminants were observed in the library area by the authors. Although beyond the scope of this study, ventilation was later found to be deficient in the area and could have contributed to the headache and fatigue components of the complaints.

Interviews with building personnel revealed that major roof leakage had occurred intermittently in the rear of the main room over a two-year period and had been permanently repaired several months prior to the authors' investigation. Water-damaged ceiling tiles had also been replaced. An effort to shampoo the carpet may have exacerbated the problem due to incomplete extraction of the cleaning solution and lack of adequate ventilation. During the authors' initial inspection, damp furnishings and visible mold growth were noted in the rear of the main room. Mold was growing on the carpet, walls, shelves, and books. A mildew-like odor was present. Relative humidity was high, ranging from 72% to 78%.

Microbial test results are presented in Table 1. Airborne bacteria were considered to be in the background range and consisted of common environmental organisms. However, airborne fungi were consistently high (580 to 1300 CFU/m') and were dominated by *Aspergillus niger*, a sensitizing mold and opportunistic pathogen. Elevated levels were found in both Zones 1 and 2 (the only areas tested initially). Visible growth on books contained high surface fungal counts (greater than 10^5 CFU/in²) also dominated by *Aspergillus niger*.

Initial Remediation (In-House)

Following a standard mold/mildew clean-up conducted by in-house maintenance staff (see Methodology), librarians continued to complain of building-related symptoms. The area was reassessed to identify remaining mold residues and to develop more specific recommendations.

Inspection indicated that exposed mold growth and mildew odor had been virtually eliminated. Dehumidification had reduced relative humidity to 55%. Cleaning had been

TABLE 3

Abatement Monitoring — Airborne Fungal Sampling Results in CFU/m³

Location	Project Day: Base	One	Two	Three	Four	Five	Six
Zone 1	ND	—	—	—	—	—	807
Zone 2	269	—	1410	—	—	—	1355
Zone 3	163	1410	—	—	502	—	1084
Adjacent Corridor (A)	32	113	—	—	456	502	1873
Adjacent Corridor (B)	67	—	25	—	—	134	—
Outside Air	194	—	—	—	—	—	1679

Notes: Five pre-abatement surface samples ranged from ND-180 CFU/in².
Fifteen surface samples during abatement ranged from ND-3 CFU/in².
ND = not detected

TABLE 4

Clearance Samples (Day 18) — Fungal Sampling Results

Location	Airborne Fungi (CFU/m³)	Fungal Types
Zone 1	65	Cladosporium sp. Penicillium sp. *Mycelia sterilia*
Zone 2	189	Cladosporium sp. *Mycelia sterilia* Penicillium sp.
Zone 3	426	Cladosporium sp. Rhizomucor sp. Epicoccum sp.
Adjacent Corridor (A)	159	Cladosporium sp. Penicillium sp. Alternaria sp.
Outside Building	742	Cladosporium sp. Aspergillus sp. Fusarium sp.

TABLE 5

One Year Follow-Up — Fungal Sampling Results

Location	Airborne Fungi (CFU/m³)	Fungal Types
Zone 1	110	Epicoccum sp. Penicillium sp. Cladosporium sp.

only partially effective, with visible dust still observed on approximately 10% of the library shelf surface area. About 1% of the books showed signs of mold growth upon close examination. Inspection of the space also revealed mold growth behind baseboards and on insulation pads associated with air supply vents. Water stains and collected dust were noted in many luminaries (light coverings that also provided slots to the return air plenum). Two air handlers that had recirculated air from the contaminated zone were also examined. Internal surfaces, including insulation, were in need of cleaning.

More detailed microbial sampling was conducted at this time in order to better delineate the affected area and locate additional sources. Total airborne fungal counts were lower (42 to 85 CFU/m³). Although this may have reflected the use of disinfectants, it should be noted that the facility was virtually closed on the test day. Under quiescent conditions, microbial concentrations tend to be lower and may not be representative of levels occurring under higher occupancy. Samples dominated by *Aspergillus niger* were assumed to indicate areas affected by the mold problem. These occurred throughout Zones 1, 2, and 3, their boundaries coinciding with the areas served by one major air handler.

Air sampling conducted in the adjacent HVAC zone (main corridor) contained no *Aspergillus niger*. An air sample in the above-ceiling return air plenum in Zone 1 contained *Aspergillus niger* in the same amount as adjacent room air. This suggested that the plenum served to transmit, but not amplify, the contaminant. Diagnostic testing was also conducted on library carpet and drapes. These were found to contain elevated mold counts, suggesting that porous materials continued to collect, grow, and release mold in the area of concern. Surface swabs of shelves revealed that *Aspergillus niger* was present, but at low amounts. This suggested that hard surfaces were less significant sources than porous materials and had been (at least temporarily) disinfected to a background level. Results of the second sampling phase can be found in Table 2.

Comprehensive Abatement

Systematic cleaning, disinfection, or removal of mold sources was accomplished by a commercial cleaning contractor (specializing in fire and water restoration and hospital maintenance) over a seven-day period. The specifications were followed in detail (see Appendix). Work proceeded from the most contaminated to the least contaminated areas and, within a given space, from top to bottom. The HVAC system remained off and occupants were excluded from the work areas. Plastic barriers were maintained at entries to adjacent spaces with smoke tube observations indicating work areas were either neutral or negatively pressured. Twelve thousand library books were examined. About 1% were discarded due to visible mold growth with the remainder of the books HEPA vacuumed and placed in temporary storage. Carpet removal appeared to be the operation with the greatest potential for spore release and was accomplished with minimal airborne dust generation. Disinfection contact time complied with specifications and was followed by protection of cleaned surfaces from recontamination.

Results of monitoring conducted during abatement can be found in Table 3. Air quality in active work areas was not measured (due to a focus on protecting occupied areas). Airborne fungal counts in Zones 2 and 3 ranged from 502–1410 CFU/m³. Readings in the adjacent HVAC zone remained at background levels for the first four work days, then rose to 1873 CFU/m³ on day five. Final cleaning was completed on day six. Air samples collected in the work areas two hours after completion of work remained elevated (807 to 1355 CFU/m³), apparently reflecting the disturbance caused by the cleaning process. Surface samples collected from cleaned surfaces and in adjacent zones during the abatement period all had low fungal counts.

Final Clearance

Final testing was delayed in order to let the space achieve equilibrium under the new conditions. With major mold sources apparently controlled, time was needed for air exchange, filtration, and settling to reduce airborne concentrations created by the recent disturbance. Final air tests were conducted on day 18 of the project (see Table 4). Samples from Zones 1, 2, and 3 now contained no *Aspergillus niger*, with counts reflecting normal background levels. Results met all clearance criteria including inside counts (65 to 426 CFU/m³) lower than outside (742 CFU/m³). A review of surface sampling data and visual inspections also indicated that all abatement obligations had been met. Under these conditions, the library was reopened.

Follow-Up Testing

One year after the abatement project, the library was retested for airborne fungi to evaluate the long-term effectiveness of the procedure utilized. In some microbial decontamination projects, only temporary reductions are achieved and conditions promoting renewed growth reoccur.

A single air sample was conducted in the worst-case location (Zone 1) under typical occupied conditions. Airborne fungi remained in the low background range (110 CFU/m³) and did not contain *Aspergillus niger* (see Table 5). This limited sampling suggests that air quality had remained stable over a one-year period.

DISCUSSION

Although this investigation is reported as a case study, certain observations may provide general guidance for the implementation of similar projects.

Interpretation of Microbial Results

Microbial sampling results are subject to wide variability and cannot be compared to precise standards or action levels (ACGIH 1987). The decision-making process that led to a determination that airborne mold levels posed an immediate problem in the library was as follows:

1. Preliminary inspection revealed major water incursion and obvious microbial growth.
2. All airborne fungal counts were above 500 CFU/m³ (upper limit of the typical range found in "non-problem" buildings based on the authors' experience).
3. All samples were dominated by a mold not common in outside air and known to be an opportunistic pathogen.
4. Health questionnaires indicated that employees were experiencing allergenic symptoms consistent with exposure to microbial sensitizers in the workplace.

Developing the scope of work for microbial remediation requires the delineation of boundaries for the contaminated area and the identification of microbial reservoirs which are contributing to elevated airborne levels. In this assessment, rooms were categorized into apparent homogeneous areas based on visual inspection, history of water incursion, and ventilation. Limited sampling was then conducted to help estimate relative contamination within each area. Following this approach, Zone 1 was concluded to be most contaminated, while Zones 2 and 3 were assumed to be contaminated to a lesser degree. Other building areas were considered to be not affected. Microbial reservoirs were similarly located (or assumed) by a combination of visual inspection, building history, and sampling. Moist interior surfaces appeared to be the original or primary source of mold growth. Secondary sources were considered to be porous materials that had contacted mold-contaminated air. Primary sources included books, ceiling tiles, and carpets, while secondary sources included drapes and HVAC insulation.

The influence of building activity on microbial sampling results may be an important consideration when conducting an environmental assessment. On the second sampling visit to the library, the facility was essentially closed and airborne mold counts dropped sharply. Occupant complaints persisted through this period and subsequent measurements were elevated. Although this temporary reduction was partly attributed to the partial clean-up conducted by in-house personnel, the lack of air movement and surface disturbance may have also been important factors. As a precaution, in subsequent projects the authors have attempted to either conduct airborne microbial sampling under typical activity conditions or use aggressive sampling techniques (i.e., operate a fan in the area to simulate occupant activity).

Laboratory turnaround time for abatement monitoring was three to five days. This raised questions as to what role microbial sampling could play in day-to-day decisions on the project. In contrast, turnaround time for fiber counts in asbestos abatement projects can be as short as one hour, allowing for rapid adjustments in the event that problematic levels are detected. In the library project, decisions on the adequacy of containment were based on observations of the industrial hygienist (i.e., compliance with specifications, integrity of barriers, presence of dust, or odor outside work area). Daily microbial counts provided documentation of project conditions after the fact. If the project had been continued beyond six days, adjustments would have been made based on elevated readings in adjacent areas. In subsequent projects involving demolition of materials with microbial contamination, the authors have used direct reading instrumentation for the measurement of respirable suspended particulates (RSP) as a surrogate for microbial levels. Elevated RSP are then assumed to be an indicator of microbial contamination escaping the containment. It should be noted that, in the absence of significant demolition dust, RSP may not be a good surrogate for airborne microorganisms. Microscopic examination of spore traps might provide another approach for monitoring microbial abatement projects.

In retrospect, the results of surface sampling were not critical in documenting progress on this project. Once disinfection efforts were initiated, swab samples of surfaces were consistently in the background range. In subsequent projects, the authors have placed lower emphasis on surface sampling.

The clearance of microbial abatement projects is a subject that has received little attention. Even well-controlled demolition and cleanup work can generate high microbial exposure levels. Before safe reoccupancy can be assured, a

period of time is needed for airborne microorganisms temporarily released during the abatement process to diminish to a new equilibrium level. Analysis of air samples may require another several days. Setting clearance criteria for microbial abatement is difficult due to the wide variation of background fungi and bacteria (generally less than 500 CFU/m^3) and the influence of outdoor levels. In this project, the primary clearance goal was for inside counts to be less than outdoor counts. If outdoor levels were low on the day of sampling, a secondary goal of 500 CFU/m^3 was acceptable. These criteria were based on the author's judgment as to a reasonable level of control that could be achieved with a microbial abatement project which would also provide a reasonable level of certainty that background levels would be maintained in the project area.

Abatement Specifications

In recent years, minimum standards for the demolition of asbestos-containing materials have been clearly defined (US EPA 1985). These include worker protection, containment, dust control, clean-up, and air quality. With similar, micron-range particles to consider, the demolition of materials heavily contaminated with mold or bacteria would appear to necessitate many of the same precautions. Fundamental differences with the asbestos model include lower health risks (if organisms are nonpathogenic) and the need for disinfection. At the present time, there are no requirements for microbial abatement and no detailed guidance is available.

Preliminary, in-house cleaning efforts to control the library mold problem were not effective in this case study for a variety of reasons, including the following:

1. The extent of the clean-up area was based on visible microbial growth, representing less than half of the area later found to be contaminated.
2. Disinfection was not conducted systematically, leaving some surfaces contaminated.
3. The cleaning of porous, heavily contaminated materials (carpets, drapes, books, etc.) was ineffective and these items needed to be replaced.
4. With a lack of containment, mold spores disturbed by the cleaning efforts are likely to have been disseminated to surrounding areas.

The subsequent comprehensive abatement effort was based on a detailed identification of microbial reservoirs and systematic procedures and proved to be much more effective than the in-house response.

One potential problem noted during the abatement project was elevated fungal counts outside the work area. This might have been controlled by placing the work area under a stronger negative pressure (the library was actually neutral to the rest of the building during much of the work). More complete containment and increased negative pressure would have the dual advantage of preventing leakage and cleaning air at the work site. While air exhausted from asbestos containments must be HEPA filtered, the direct discharge of nonpathogenic molds or bacteria by fans to the outside environment may be acceptable.

Personal protection was not a significant issue during the project. Although half-face respirators with HEPA filters were recommended, most workers and inspectors wore simple dust masks without any discomfort. More protective measures would have been needed for persons who were allergy-prone or immunocompromised.

The precautions needed for implementing other microbial abatement projects might be more or less stringent than those followed in this case study based on site-specific factors such as the following:

1. Types and numbers of organisms involved.
2. Scope of work and areas affected.
3. Magnitude of disturbance involved.
4. Proximity of occupants.
5. Sensitivity of occupants.

CONCLUSIONS

1. The library investigated had a significant microbial contamination problem, as reflected in high airborne concentrations of *Aspergillus niger*.
2. Initial in-house clean-up efforts were not successful because of a failure to identify and remove or disinfect all reservoirs of mold growth.
3. A detailed abatement effort permanently reduced airborne fungal counts to background levels and eliminated *Aspergillus niger* from subsequent air samples (see Figure 2).

RECOMMENDATIONS

Guidance is needed for conducting large-scale microbial abatement projects. Flexible standards are needed which allow such work to be implemented effectively and safely while accounting for a broad range of site-specific conditions. Experience in this case study suggests that special attention will be needed when developing standard procedures for the following areas:

1. Determining contamination boundaries and identifying reservoirs of microbial growth.
2. Containing and ventilating work areas.
3. Cleaning, disinfecting, or replacing contaminated surfaces.
4. Monitoring active abatement areas (including visual inspection, direct-reading instrumentation, and microbial sampling).
5. Clearance criteria.

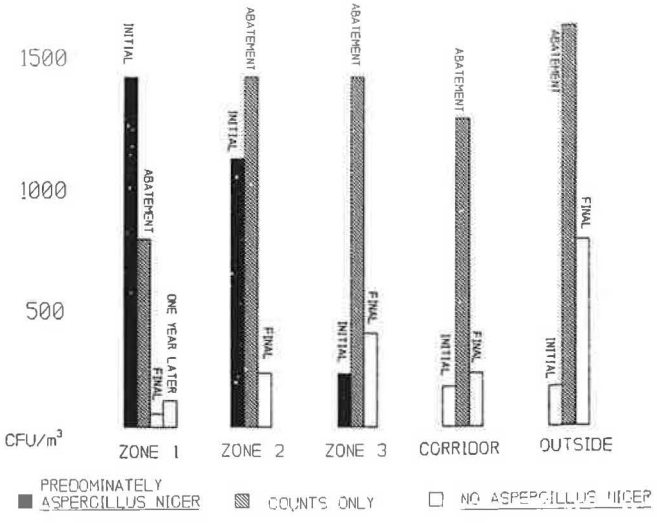

***Figure 2** Comparison of peak fungal counts*

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APPENDIX

Specifications Used for the Cleaning and Disinfection of Mold-Contaminated Library

Zone 1

1. Clean and disinfect Room A according to Zone 2 procedures, as indicated below.
2. HEPA vacuum all computer equipment, readers, and similar electronic equipment thoroughly; move into Room A and wrap in plastic sheet.
3. HEPA vacuum all audio/visual equipment in the audio/visual room.
4. HEPA vacuum all books in library. Start with books at east end and work to west end of room. Each book should be opened first to look for visible signs of mold. Those in this condition should be placed in a designated box for further action later. Those not showing visible signs of contamination should be packed in a box after vacuuming.
5. Prior to handling the library's drapes and carpet, the room must be secured to prevent unauthorized entrance and to minimize the likelihood of cross-contamination by the following procedure:
   a. Remove all drapes from Zone 2 offices and carefully place in plastic bag (see step 6 below).
   b. Seal all doors from the library side with plastic sheeting, except Room B, which will be used by designated individuals as an entrance and exit.
   c. HEPA vacuum the floor of Room B at least twice a day.
   d. Test the airflow differential between the library and adjacent areas to help ensure that the room is operated under one of two conditions: neutral or negative pressure to the surrounding public spaces. Ventilation smoke tubes will be used for this determination. Both air handlers will be shut down and made inoperable during this phase.
6. Remove drapes carefully from library and immediately place in plastic bags. Seal immediately to minimize dissemination of spore clouds.
7. Remove carpet in sections starting with east side of room first. Seal carpet section in plastic sheeting immediately.
8. Remove all plastic-bagged curtains and plastic-wrapped carpeting from the library through window. Wait approximately 2 hours settling time before proceeding with step 9.
9. Remove ventilation grilles; clean and disinfect with a combination detergent/disinfectant product containing a substituted phenolic-type disinfectant at the maximum use dilution recommended by the manufacturer; discard insulating pad associated with each air supply vent; HEPA vacuum ventilation supply ducts to the distance practical.

NOTE: Disinfectants typically take 20 to 30 minutes of *wet* contact time to achieve the desired level of disinfection. All disinfected surfaces should remain visibly wet for at least 20 minutes. Follow with clean water rinse if indicated by product manufacturer. Wipe up excess or standing water.

10. Remove all luminaries from the light fixtures; clean and disinfect using combination detergent/disinfectant, as indicated above.
11. HEPA-vacuum the ceiling.
12. HEPA-vacuum all walls or wall hangings.
13. HEPA-vacuum the floor.
14. Spray the floor with substituted phenolic disinfectant at indicated maximum use dilution.
15. HEPA-vacuum, then clean and disinfect all book shelves and furniture.

Zone 2

1. Remove all plastic sheeting from doors.
2. Remove all luminaries from the light fixtures; clean and disinfect as indicated.
3. Remove ventilation grilles; clean and disinfect as indicated; discard insulating pads; HEPA vacuum ventilation supply ducts as far as practical.
4. HEPA-vacuum all exposed horizontal surfaces.
5. Clean and disinfect floors using wet mopping technique for hard floors and disinfect carpet using disinfectant carpet shampoo. All disinfectant products will be of the substituted phenolic type.

Zone 3

1. Remove all stained or soiled luminaries from the light fixtures; clean and disinfect as indicated.
2. Follow steps 3 through 5 as indicated for Zone 2.

Air-Handling Equipment

1. Seal off the supply ducts of both AHUs prior to start of cleaning/disinfecting procedures.
2. Turn off units and lock out activation controls. Open AHUs carefully and without banging hatches (or covers) and ductwork to minimize aerosolization of microbes.
3. Carefully remove debris and filters by appropriate means.
4. Use the detergent/disinfectant product, as previously specified to thoroughly saturate (by low-pressure spray action) the entire interior of the unit including coil, condensate pan, fan and housing, filter rack, and insulation. Inaccessible insulation should be thoroughly saturated with the detergent/disinfectant. Be sure to spray any dampers (both sides) that are accessible in the unit. Follow with clean water rinse. Wipe or wet-vacuum excess or standing water.
5. Pressure-clean coils with an appropriate coil cleaner product using the least amount of pressure possible and still

achieve desired results. Wipe or wet-vacuum standing liquid in the AHU.

6. Encapsulate accessible insulation inside air handlers with an appropriate sealant.
7. Remove diffuser boxes associated with each air supply vent. Clean, disinfect, and encapsulate inside surfaces.

DISCUSSION

James V. Dirkes II, University of Michigan, Ann Arbor, MI: How many books were discarded and what percentage of the overall improvement do you attribute to that action?

E.N. Light, Biospherics Inc., Beltsville, MD: Approximately 200 books with visible mold growth were discarded from the library. Their precise contribution to airborne mold concentrations (as compared to carpets, insulation, and other surfaces) could not be determined.

Carl N. Lawson, LRW Engineers Inc., Tampa, FL: After all the work and testing were completed, did you increase the outside air requirements of this facility?

Light: Although not specifically measured during the initial study, ventilation deficiencies probably contributed to the moisture/mold problem. Ventilation appeared to be increased due to the cleaning of air handler coils during the project. As a follow-up measure, HVAC controls were repaired and the system was balanced.

Marian Heyman, Hartford Steam Boiler, Hartford, CT: If valuable book materials were present in the library, was consideration given to sterilizing these materials with an ethylene oxide autoclave?

Light: In this situation, no rare books were present and all contaminated volumes could be replaced. For more specialized holdings, sterilization would have been considered.