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Microbiological Events After a Fire in a High-rise Building

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Abstract

Water used to control a fire on an upper floor in a high-rise office building wetted furnishings and construction materials on lower floors and resulted in the amplification of microorganisms especially mesophilic and thermotolerant fungi. Concentrations of fungi in indoor air including Aspergillus, Penicillium *and* Paecilomyces *approached or exceeded 10^4 colony forming units per cubic meter (cfu/m^3). Airborne endotoxin levels increased about 1 order of magnitude over background levels. Sampling for fungi using both culture plate impactors and spore traps showed that spores were migrating from water damaged to undamaged areas in the office complex. Elevator shafts traversing water damaged floors likely provided the major dispersion pathway of spores into occupied areas. Construction materials such as plaster ceilings that had been wetted during the fire but were free of visual fungal contamination were found to be strong fungal reservoirs after the building had thoroughly dried. Management of microbial contaminants after a fire in a high-rise building is an important public health concern and therefore an essential aspect of building restoration.*

KEY WORDS:
Aspergillus, Building restoration, Endotoxin, Fire, Fungi, Water damage.

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Introduction

Elevated concentrations or unusual kinds of microorganisms have been reported in buildings affected by acute or chronic moisture problems. For example, moist components in heating, ventilation, and air-conditioning (HVAC) systems including heat exchangers and their drain pans, humidifiers and water sprays, air handling unit plenums, and internal insulation in the air conveyance system can each become strong amplifiers for fungi if maintenance is not fastidious (Morey, 1990; Morey et al., 1986). Fungi may massively contaminate porous finishing materials such as ceiling tiles and gypsum board in buildings where relative humidity including equilibrium relative humidity (ERH) in substrates is elevated because of failure of the HVAC system to remove latent heat or where wall and ceiling systems become moist because of chronic leaks or water vapor migration associated with inadequate placement of vapor retarders (Morey, 1992; Odom, 1992). Other kinds of microorganisms including thermophilic bacteria (Banaszak et al., 1970), thermotolerant fungi (Morey, 1984), and gram-negative bacteria (Rylander et al., 1978) can amplify in buildings damaged by water leaks or in poorly maintained HVAC system components.

While water disasters are occasionally reported in large commercial buildings (Hodgson et al., 1985) the degree to which finishings and construction materials become soaked is probably most extensive after a fire occurs on the upper floors of a high-rise structure. Millions of liters of water may be used to extinguish the fire and most of that water flows into lower floors soaking room contents and ceiling, wall, and floor systems. Removal of moisture from floors not directly affected by the fire but soaked by water runoff may take weeks or months during which fungi and bacteria can proliferate on building finishing and construction materials.

This case study describes the microbiology that

occurred in a high-rise building complex over a period beginning 3 months after a fire when construction and finishing materials were still moist and concluding 5 months later when water damaged portions of the building were thoroughly dry. The objectives of the study were to describe the kinds of bioaerosol exposures that can occur both for occupants in portions of the building unaffected by the fire or water damage and for workers involved in removal of water damaged finishing and interior construction materials.

Methods

Air sampling for fungi and bacteria was performed with a single stage sieve (219 jets) culture plate impactor operating at a flowrate of 0.18 cubic meters (m^3) per minute. Air volumes for impactor samples varied from 0.06 to 0.32 m^3. Malt extract agar (2% malt extract, 2% dextrose, 0.1% peptone) was used for the growth of mesophilic (23 to 28 C) and thermotolerant (45 C) fungi. Tryptic soy agar (55 C) and MacConkey agar (23 to 28 C) were used to grow thermophilic bacteria and gram negative bacteria, respectively. Spore traps operating at 0.01 m^3 per minute were used to collect fungi on greased glass slides for direct microscope enumeration and identification. Air volumes for spore trap samples varied from 0.02 to 0.08 m^3. Airborne endotoxin was collected by filter cassette samplers (0.01 m^3 per minute), on polycarbonate membrane filters (pore size 0.4 micrometers) and analyzed by a modifier Limulus method (Milton et al., 1990). Air volumes for filter samples varied from 0.8 to 2.5 m^3. All air samples were collected quiescently, that is, under normal operating conditions without disturbance of floor, wall, or ceiling systems or movement of room contents. Air samples from water-damaged areas of buildings were collected at approximately the same time of the day as parallel samples obtained in non-damaged areas or in the outdoor air.

Weighed samples of finishing materials such as gypsum board (3 samples, floor 3, Building A), carpet (2 samples, floors 4 and 6, Building A), and insulation (2 samples, mechanical equipment room on floor 2) collected 3 months after the fire were shaken in sterile water and the effluent was serially diluted onto malt extract agar for enumeration and identification of mesophilic and thermotolerant fungi.

Background

A fire burned for 2 1/2 days on the ninth floor of a 10-story tower (Building A) in a North American city. Building A is directly connected on its east side by hallways to the first 10 stories of an adjacent 18-story office tower (Building B) which itself is connected by hallways to the lower 18 floors of a 20-story office tower (Building C). Over 80 million liters of water were used to extinguish the fire on the ninth floor of Building A. This resulted in the soaking of furnishings (for example, furniture, files, and modular partitions) and interior construction and finishing materials (for example, wood paneling, gypsum board walls, carpet, and plaster ceilings and walls) on lower floors of both Buildings A and B.

The HVAC system of both Building A and the water-damaged floors of Building B was damaged by the fire and remained inoperational throughout the duration of the study.

The upper eight floors of Building B and all floors of Building C were unaffected or only minimally affected by smoke and water damage. The offices on these floors remained occupied after the fire. Elevators in both Buildings B and C remained operable. Acess to water or fire-damaged floors in Buildings A and B (floors 1 through 10) was made primarily through elevators in Building B (elevators absent in Building A).

Results and Discussion

Evaluation Three Months After The Fire

Three months after the fire, interior furnishings and construction materials in Building A were still moist. Relative humidity (direct-reading instrument; thin film capacitive sensor) and dry bulb temperature indoors were as high as 70% and 42°C, respectively. Visible fungi in Building A were observed on surfaces of carpets, furniture, modular partitions, gypsum board, wood paneling, ceiling tiles, and marble and plaster walls.

Sampling for mesophilic fungi and other bioaerosols was carried out at an outdoor control location on the roof of Building C (21st level) remote from external contamination sources such as cooling towers, exhaust vents, or vegetation. The concentration of mesophilic fungi ranged from 110 to 600 cfu/m^3 with *Cladosporium* being the dominant isolate (Table 1). Some *Penicillium* and *Paecilomyces* and lesser concentrations of *Alternaria, Fusarium, Epic-*

Table 1 Air sampling for mesophilic (23–28°C) and thermotolerant (45°C) fungi 3 months after the fire

Location	Concentration range and taxa
Outdoors, roof of Building C	Mesophilic fungi: 110 to 600 cfu/m^3; *Cladosporium* dominates 9 of 11 samples; *Penicillium* and *Paecilomyces* each dominate 1 sample. Thermotolerant fungi: 8 to 11 cfu/m^3; *Aspergillus niger* dominates both samples
Building A, samples on floors 2, 3 and 6	Mesophilic fungi: 500 to $>10^4$ cfu/m^3; *Aspergillus* dominates 5 of 7 samples; *Penicillium* dominates 2 of 7 samples. Thermotolerant fungi: 100 to 3,000 cfu/m^3; *Aspergillus* dominates 5 of 6 samples; *Paecilomyces* dominates 1 of 6 samples
Building B, elevator foyer on 16th floor	Mesophilic fungi: 1,100 to $>10^4$ cfu/m^3; *Penicillium* dominates all 3 samples
Building B, occupied areas on floors 11, 13 and 16	Mesophilic fungi: 50 to 360 cfu/m^3; *Penicillium* dominates 5 of 7 samples; *Sporobolomyces* dominates 2 of 7 samples
Building C, elevator foyers on floors 6 and 9	Mesophilic fungi: 40 to $>10^4$ cfu/m^3; *Penicillium* dominates 4 of 5 samples; *Aspergillus* dominates 1 of 5 samples

< means greater than; cfu/m^3 means colony forming units per cubic meter of air

occum, Aspergillus, Aureobasidium, Curvularia, Pithomyces, and *Botrytis* were found in outdoor air samples.

Concentrations of mesophilic fungi ranging from 500 to $>10^4$ cfu/m^3 were found in Building A (Table 1). *Aspergillus* (mostly *A. niger;* lesser concentrations of *A. versicolor* and *flavus*) and *Penicillium* dominated most indoor air samples. One sample (air volume 0.06 m^3) collected on the third floor of Building A contained *Aspergillus, Penicillium,* and *Paecilomyces* at each of the 219 impaction points on the culture plate used in the sampler (concentration of each genus exceeded 10^4 cfu/m^3).

In occupied spaces of Building B, concentrations of mesophilic fungi ranged from 50 to 360 cfu/m^3 (Table 1). *Penicillium* and *Sporobolomyces* were the dominant isolates in these samples. *Sporobolomyces* was not detected in any outdoor air samples.

Eight mesophilic fungi samples were collected in elevator foyers in Buildings B and C (Table 1). *Penicillium* and *Aspergillus* were the dominant isolates and in some samples the concentration of *Penicillium* was as high as 10^3 or 10^4 cfu/m^3.

The collective air sampling results suggested that strong amplification sites for mesophilic fungi especially *Penicillium* and *Aspergillus* were present in Building A. In addition, the high concentrations of these fungi found in Buildings B and C were judged to be atypical of those normally present in indoor environments (ACGIH, 1989; Miller, 1992); that is *Penicillium, Aspergillus,* and *Sporobolomyces* found in Buildings B and C do not normally dominate the air of buildings. The high concentrations of *Penicillium* found in some elevator foyers suggested that the elevator and the hallways connecting the common floors of Buildings A, B, and C were acting as conduits for the dispersion of bioaerosols from water damaged portions of the building complex to occupied areas.

Sampling for thermotolerant fungi was performed 3 months after the fire in Building A and in the outdoor air (Table 1). The concentration of thermotolerant fungi outdoors ranged from 8 to 11 cfu/m^3 (mostly *Aspergillus niger*) while that in Building A varied from 100 to >3,000 cfu/m^3. *Aspergillus* (mostly *A. niger;* some *A. flavus* and *A. versicolor*) and *Paecilomyces* were the dominant thermotolerant isolates. Lesser concentrations of *Penicillium* were also present. These air sampling results showed that Building A was a strong amplification site for thermotolerant fungi.

Bulk or reservoir samples were collected from insulation on hot and cold water pipes, from gypsum board, and from carpet (most samples visibly contaminated by fungi) of Building A and examined for the presence of mesophilic and thermotolerant fungi. *Aspergillus* (mostly *A. niger;* some *A. flavus* and *A. versicolor*), *Penicillium,* and *Sporobolomyces* were the predominant mesophilic fungi present at a concentration range of approximately 10^5 to 10^7 cfu per gram. The concentration of thermotolerant fungi in the same bulk samples was approximately 10^4 to 10^6 cfu per gram with *Aspergillus (A. niger* and *A. fumigatus)* and *Paecilomyces* being the dominant isolates. The gypsum board, carpet, and insulation materials from Building A thus appeared to be major sources of the airborne mesophilic and thermotolerant fungi detected in Building A.

Air sampling for thermophilic bacteria was performed in Building A and in the outdoor air. One or two actinomycete colonies were present in a few indoor and outdoor samples. However, most air

samples were negative for actinomycetes and other thermophilic bacteria. Building A therefore did not appear to be an amplification site for these kinds of microorganisms.

Sampling for endotoxin was carried out in Building A and in the outdoor air 3 months after the fire (Table 2). Endotoxin concentrations in Building A ranged from 0.15 to 3.1 nanograms per cubic meter of air (ng/m^3) which was about 1 order of magnitude higher than that found outdoors. These analytical results suggested that some amplification of gram negative bacteria had occurred in Building A.

The following recommendations (for details see Morey, 1992) were made and subsequently carried out by the owner to control microbial contamination in Building A: (a) Negatively pressurize water-damaged areas of Buildings A and B relative to occupied floors. Erect physical barriers between water-damaged and occupied areas. Control foot traffic patterns so that workers do not track spores from water damaged to occupied areas. (b) Discard water-damaged finishing and construction materials especially those visually contaminated by fungi. Personal protective equipment including a respirator with high efficiency particulate air (HEPA) filters (powered air purifying device is best) is required (Morey, 1992) for remediation workers removing furnishings and finishing and construction materials visually contaminated by fungi such as in Building A. (c) Use a vacuum with a HEPA filter to remove settled dusts and spores from hallways and elevator foyers connecting water-damaged and occupied areas. Use a HEPA vacuum to remove residual dusts in Building A after water damaged materials have been discarded.

Table 2 Airborne endotoxin in outdoor air and in buildings A and C at various times after the fire

Months after fire	Location	Endotoxin concentration
Three	Outdoors, roof of Building C (2)	0.12 to 0.15 ng/m^3
Three	Building A, floors 2 (3) and 6 (3)	0.15 to 3.1 ng/m^3
Five	Outdoors, roof of Building C (3)	0.07 to 0.10ng/m^3
Five	Building A, floors 2 (1) and 6 (2)	1.2 to 2.7 ng/m^3
Five	Building C, floors 9 (2) and 16 (2)	0.12 to 0.56 ng/m^3
Eight	Outdoors, roof of Building C (3)	0.06 to 0.07 ng/m^3
Eight	Building C, floors, 2, 5, 8, 11, 14, and 18 (1 on each floor)	0.02 to 0.11 ng/m^3

ng/m^3 means nanograms of endotoxin per cubic meter of air. Samples on each floor indicated by number in parentheses.

Evaluations Four to Six Months After The Fire

Additional air sampling for mesophilic and thermotolerant fungi was performed in Buildings A, B, and C 4 to 5 months after the fire. Much of the moisture associated with water damage had been removed by 5 months after the fire. Relative humidity in Building A was primarily in the 30 to 60% range. The relative humidity and dew point temperature in Building A tracked outdoor conditions because the ventilation system was inoperable.

Mesophilic *Aspergillus niger* and *A. versicolor* (concentration 500 to $>10^4$ cfu/m^3) dominated (sometimes 100% of isolates) all samples collected in Building A 4 months after the fire (Table 3). *Aspergillus* still dominated the fungi present in elevator foyers of Building B (six of nine samples; see Table 3) but the concentration of fungi present 4 months after the fire was less (concentration range 40 to 700 cfu/m^3) than that 1 month earlier (concentrations up to 10^4 cfu/m^3; compare Tables 1 and 3). Concentrations of fungi in occupied areas of Building C 4 months after the fire were also considerably lower than those a month earlier. Reduction in fungal concentrations in Buildings B and C was likely due to containment and control measures that had been initiated by the owner.

Thermotolerant fungi especially *Aspergillus* and *Paecilomyces* (concentrations as high as $>10^4$ cfu/m^3) were still abundant in Building A 5 months after the fire indicating that drying of the building had not affected viability of spores. Concentrations of thermotolerant fungi in elevator foyers of Building B and in occupied spaces of Building C were low (28 cfu/m^3 and less) and comparable to those found in outdoor air (Table 3). Measures to prevent dispersion of thermotolerant fungi from reservoirs in Building A to occupied spaces elsewhere in the building complex appeared to be effective.

Air sampling for endotoxin and gram negative bacteria was performed in Buildings A and C and in the outdoor air 5 months after the fire. In the outdoor air concentrations of endotoxin ranged from 0.07 to 0.10 ng/m^3 (Table 2). In Building A concentrations of endotoxin were approximately 1 order of magnitude greater than those outdoors.

Table 3 Air sampling for mesophilic fungi 4 months after the fire and for thermotolerant fungi 5 months after the fire

Location	Concentration range and taxa
Outdoors, roof of Building C	Mesophilic fungi: 60 to 900 cfu/m^3; *Cladosporium* dominates 5 of 7 samples; *Penicillium* and yeasts each dominate 1 of 7 samples. Thermotolerant fungi; < LOD to 22 cfu/m^3; *Aspergillus fumigatus* and *niger* dominate 5 of 6 samples. Fungi not detected in 1 sample (LOD = 3 cfu/m^3)
Building A, 23–28°C fungi on floors 2, 3, 4, and 6; 45°C fungi on floors 3, 4, and 7	Mesophilic fungi: 500 to > 10^4 cfu/m^3; *Aspergillus* dominates all 8 samples. Thermotolerant fungi: 40 to > 10^4 cfu/m^3; *Paecilomyces* dominates 7 of 10 samples; *Aspergillus* dominates 2 of 10 samples; Non-sporulating fungi dominate 1 of 10 samples
Building B, 23 to 28°C and 45°C fungi in elevator foyers on floors 11, 13 and 16	Mesophilic fungi: 40 to 700 cfu/m^3; *Aspergillus* dominates 6 of 9 samples; *Penicillium* and *Cladosporium* dominate 2 and 1, respectively of remaining samples; Thermotolerant fungi: 6 to 28 cfu/m^3; *Paecilomyces*, *Aspergillus*, and *Penicillium*, respectively dominate 4, 3 and 1 of 8 samples
Building C, 23 to 28°C fungi in offices on floors 2, 6, and 15; 45°C fungi in elevator foyers on floors 2, 6 and 9	Mesophilic fungi: 3 to 380 cfu/m^3; *Penicillium* dominates 4 of 6 samples; *Aspergillus* and yeasts each dominate 1 of 6 samples. Thermotolerant fungi: < LOD to 6 cfu/m^3; Fungi not detected in 5 of 7 samples (LOD = 3 cfu/m^3); *Aspergillus* and non-sporulating fungi each dominate 1 of 7 samples

LOD means limit of detection

However, endotoxin levels in Building C were only slightly greater than those outdoors.

Concentrations of gram negative bacteria outdoors and in Building C were similar (maximum level of 17 cfu/m^3). A slightly elevated concentration of gram negative bacteria (maximum concentration 119 cfu/m^3) was present in Building A with *Aeromonas*, *Citrobacter*, and *Alcaligenes* being the dominant taxa present.

Air sampling by spore trap was performed 5 and 6 months after the fire as Building A continued to dry. By 6 months after the fire, the relative humidity in Building A was in the 20 to 35% range. Spore trapping was used because of the possibility that some fungi might lose viability as the drying process continued and because the great majority of fungal spores in air are known to be nonviable and undetectable by culture collection methods (Burge et al., 1977).

Analytical results from spore trap collections made 5 and 6 months after the fire are presented in Table 4. All samples collected in Building A were dominated (75 to 95% of spores) by spores with *Penicillium-Aspergillus* type morphology (concentration range, approximately 10,000 to 50,000 spores/m^3). By contrast in Buildings B and C and in the outdoor air, the total spore concentrations did not exceed 4,000/m^3. While some *Penicillium-Aspergillus* spores were found in Buildings B and C, this kind of spore dominated only a minority of the samples. Outdoor-sourced spores such as *Cladosporium* and mushroom-type spores (basidiospores) were also commonly present in Buildings B and C (Table 4).

It was concluded that 6 months after the fire fungal aerosols in Building A were still atypical of those normally found in buildings or in the outdoor air. Strong reservoirs or emission sites of fungi still existed in Building A.

Evaluations Seven to Eight Months After the Fire

By 7 months after the fire, most furnishings damaged by water had been removed and interior construction materials such as plaster walls and ceilings were dry.

The plaster ceilings in Buildings A and B are located about 1/2 meter below the concrete deck of the next floor above. Some of the lower surfaces of the plaster ceiling in Building A were water stained but visual evidence of fungal growth was absent. Access into the cavity between the plaster ceiling and the concrete floor deck was made through preexisting panel openings in the ceiling. Fungal growth on upper surfaces of the plaster ceiling (as viewed from the cavity) was not apparent.

Air sampling was performed in ceiling cavities 7 months after the fire in Building A by locating spore traps on a piece of clean metal foil on the upper surface of the ceiling in the cavity. Otherwise no disturbance to the ceiling cavity was made during sampling. Sampling was also performed in a control ceiling cavity in Building B which had not been damaged by the fire.

Air sampling showed that the concentration of spores in the air spaces above plaster ceilings, in Building A ranged from 2.7×10^5 to 1.3×10^6/m^3 (Table 4). *Penicillium-Aspergillus* spores dominated

Table 4 Air sampling for fungi by spore trap

Location	Time after fire (months)	Concentration range (spores/m^3)	Taxa
Outdoor air, roof of Building C	5 to 6	270 to 3,800	Basidiospores dominate 4 of 8 samples; Smut and *Cladosporium* each dominate 2 samples
Building A, floors 2 and 6	5 to 6	9,500 to 52,500	*Penicillium-Aspergillus* dominate all 8 samples
Building B, elevator foyers on floors 11 and 13	5 to 6	< LOD to 4,000	*Penicillium-Aspergillus* dominate 3 of 8 samples; Fungi not detected in 2 of 8 samples (LOD = 300 spores/m^3); Basidiospores, *Cladosporium*, and unidentified spores each dominate 1 sample
Building C, elevator foyers and hallways on floors 6, 9, 15 and 16	5 to 6	< LOD to 1,850	*Cladosporium* dominates 5 of 15 samples; Fungi not detected in 6 of 15 samples (LOD = 150 spores/m^3); *Penicillium-Aspergillus* dominate in 3 of 15 samples; Basidiospores dominate 1 sample
Outdoor air, roof of Building C	7	< LOD to 1,700	*Penicillium-Aspergillus* dominate 5 of 7 samples; Fungi not detected in 2 of 7 samples (LOD = 400 spores/m^3)
Building A, above plaster ceilings on floors 3, 4 and 6	7	2.7×10^5 to 1.3×10^6	*Penicillium-Aspergillus* dominate all 9 samples
Building B, above plaster ceiling on floor 13	7	< LOD to 1,000	Fungi not detected in 3 of 6 samples (LOD = 140 spores/m^3); *Cladosporium* dominates 2 of 6 samples; *Penicillium-Aspergillus* dominate 1 sample

all air samples. Concentrations of spores above a plaster ceiling on the control floor in Building B and in the outdoor air were 2 to 3 orders of magnitude less than those in air above water-damaged plaster ceilings in Building A. These analytical results showed that even though visual contamination was not apparent, strong reservoirs of fungal spores existed in plaster ceilings that had been flooded during the fire. Plaster ceilings were subsequently demolished to remove these reservoirs.

Additional air sampling for endotoxin was performed in occupied areas of Building C 8 months after the fire. Analytical results showed that endotoxin concentrations in indoor air in Building C were at that time similar to those in the outdoor air (Table 2).

Conclusions

This case study shows that strong reservoirs and amplification sites of mesophilic and thermotolerant fungi will likely develop in interior finishing and construction materials that are wetted and allowed to remain wet after efforts to control fire in a large office building. *Aspergillus*, *Penicillium*, and *Paecilomyces* dominated the fungal aerosols present on water damaged floors of Building A 3 months after the fire. Exposure to these kinds of bioaerosols at concentrations approaching 10^4 cfu/m^3 is atypical and can in some individuals present a risk for development of allergic respiratory disease (sensitization) and possibly cytotoxic effects (ACGIH, 1989; Miller, 1992).

Endotoxin in Building A was present at a concentration about 1 order of magnitude greater than that in the outdoor air. This is probably not sufficiently elevated to be considered a health risk. Biological effects from the inhalation of endotoxin occur at exposures that are approximately 2 to 3 orders of magnitude greater than background levels (ACGIH, 1989) or above thresholds in the range of 9 to 80 ng/m^3 (Olenchock, 1990).

The collective analytical results of this case study suggest that if water damaged finishing and interior construction materials are not quickly dried out after a fire, fungi are the most important of the microbial contaminants that may grow in the building.

Building A was vacated throughout this case study. Exposure risk from fungi was thus greatest to remediation workers, contractors, consultants, and government inspectors. Personal protective equipment including a respirator with a HEPA filter was recommended for individuals in this building. Powered air-purifying devices with HEPA filters were required for remediation workers removing furnishings and construction materials visibly contaminated by fungi.

Negative pressurization of water-damaged areas and the erection of floor to slab barriers are required to prevent the dissemination of bioaerosols into portions of the building unaffected by fire or water. Elevator shafts traversing water-damaged floors may provide a pathway allowing for transport of bioaerosols into occupied spaces.

Dissemination of spores into occupied spaces can be reduced by construction of containment barriers around elevator shafts in foyer areas and by negatively pressurizing the shaft by installation of an exhaust fan on the shaft roof.

Visual inspection was not sufficient to reveal all reservoirs of fungi in Building A. While the occurrence of fungi was visually evident on gypsum board, wood paneling, painted plaster walls, carpet, and pipe insulation, fungi were not apparent on water-damaged plaster ceilings. Air sampling did show the occurrence of strong fungal reservoirs in plaster ceilings and was important in the owner's decision to remove this interior construction material.

Management of potential microbial problems following a high-rise fire is an important public health concern and therefore an essential aspect of building restoration. Following a high-rise fire, attention is commonly given to other types of contaminants such as asbestos, polychlorinated biphenyls, and smoke. Although numerical guidelines for microorganisms do not currently exist (ACGIH, 1992/93), the health risks from the inhalation of fungal aerosols are just as real as those posed by physical and chemical agents that are regulated by governmental guidelines.

Prompt attention to drying out finishing and interior construction materials is the most important aspect of microbial management during building restoration. This means that the ERH or water activity (a_w) in finishing and construction materials must be reduced below levels (ERH $< 75\%$; $a_w < 0.75$) required to support the growth of xerophilic fungi (Flannigan, 1992). Prompt discarding of materials visually contaminated by fungi (Morey et al., 1986) together with microbial air and source sampling for potential contaminants in building zones with water stained finishing and interior construction materials are necessary components of microbial management during building restoration.

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