

Physical Factors and Distribution of Fungal Contamination in a High Rise Building

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Abstract

A water event took place on the 11th floor of a 14 floor high-rise building. Water damage resulted on most of the lower floors. The building had been recently renovated for assisted living housing but was not yet occupied. The more prominent pathways for the water included the elevator shaft, plumbing chases and ventilation shafts. Our investigation and fungal sampling found fungal contamination at levels of concern below and above the 11th floor. As no water damage took place above the 11th floor, our initial, visual inspection did not raise concerns of fungal contamination in these areas.

Further investigation pointed to the elevator shaft, stairwell and common ventilation shaft as possible pollutant pathways. The common ventilation shaft was not in operation and inspection using a digital manometer indicated no pressure differences between the ventilation shaft and the interior spaces. The stairwells appeared free of water damage and were well sealed by the exit doors. Inspection of the stairwells using a digital manometer also indicated no pressure differences between the stairwell and corresponding floors.

The elevator shaft was the primary path for water runoff during the water event. Elevated fungal levels were found within the elevator shaft. Fungal testing and measurements using a digital manometer indicated noticeable pressure differentials between the shaft and corresponding floors. Negative pressures, stronger at the bottom, began to turn positive toward the upper floors, thereby confirming the “stack effect” process and providing a viable, distribution pathway for the introduction of fungal contaminants in the upper floors. Major fungal contaminants included *Penicillium* spp. and *Aspergillus* spp. *Stachybotrys* was inconsistently detected in the air, surfaces and bulk materials on the 3rd, 4th, 5th, 7th, 8th and 9th floor.

Keywords: Stack Effect, Negative Pressure, Pressure Differential Strategies, *Penicillium*, *Aspergillus*, *Stachybotrys*, Air Scrubbers, Air Washing.

Method and Material

Part 1

Fungal Contamination

The microbiological investigation involved the collection of viable and non-viable air, culturable surface swabs, tape and bulk samples on each of floors 1-11 and culturable surface swabs, tape and Air-O-Cell samples on the 12th and 13th floors. For comparison air and surface samples were collected on the outdoors in the entrance to the building. A total of two hundred seventy three (273) samples were collected where suspected or visible fungal growth was evident.

The viable air samples were collected utilizing the pre-calibrated RCS Plus Air Sampler that facilitates the quantitative analysis of airborne microorganisms from sample-volumes ranging from 10 to 1000 liters (lm³ of air). The air stream was preset at a constant rate (50L/min) at a rotor speed of 6100 rpm. The rotor contained the agar strips SDX-Sabour and Dextrose agar for fungi. The agar strips were incubated at 27 degrees Celsius for 8-10 days. Bacterial and fungal counts were determined and the number of colony-forming-units (CFU) calculated per cubic meter of air, CFU/m³.

Surface samples were collected using sterile swabs with Stuart Medium that enables survival of microorganisms and their transport to the laboratory.

The collected bulk samples were adjusted and weighed on an analytical balance. The weighed materials and the swab samples were placed in a measured amount of sterile de-ionized water, allowed to stand at room temperature for thirty minutes, vortexed vigorously and serially diluted. Following the serial dilutions the biological material is put into inhibitory mold agar (IMA) and 2 trypticase soy agar (TSA) plates. The Biotest RCA agar strips, TSA and IMA plates were subsequently incubated at 27 degrees Celsius for 8-10 days. Bacterial and fungal counts were determined and the number of CFU/m³ of air, CFU/swabs, and CFU/gram of material calculated. Transparent tape slides collected were also viewed microscopically for fungal conidia/fragments, hyphae and fungal spores and fruiting-fungal structures.

Part 2

Negative Pressurization and Filtration Devices

- a. Negative-pressure air machines were used to create the necessary negative pressure containment required by the client's consultant. The use of negative pressure in a work area is routine within the microbial abatement process. Because this project was conducted in a heavily residential area, all negative air equipment was provided with HEPA filtration to prevent microbial contamination of the ambient air.
- b. The same type of equipment was used to bring in filtered, outside air. This provided make-up air, from an intended, controlled, source, creating a controlled flow of filtered air to help air-wash the work area, and was helpful in reducing the infiltration of make-up air from unintended sources.
- c. The negative-pressure air machines, equipped with HEPA filtration, were also used as micro-traps, also known as air scrubbers, to continuously clean the air of bioaerosols and airborne particulate.
- d. Drywall and other building materials removed produced elevated airborne particulate. In addition to the use of negative pressure and micro-trap scrubbers, a cleaner/disinfectant was applied by airless sprayer to all walls, surfaces and metal studs. This application was done at as low a pressure as practical, (1,000 psi) and at a good distance from all surfaces (approx 8-10 feet). The aerolization of the cleaner/disinfectant helped to wash the air, pulling airborne particulate down to the floor. Settled particulate tended to clump together, making it heavier than normal. Consequently, this reduced the potential for disturbance and reintroduction into the air and made the HEPA vacuuming process easier and more productive.

Part 3

Physical Monitoring

DG-2 Pressure Gauge: Background

Pressure Differential Measurements were made using a DG-2 Digital Pressure Gauge, manufactured by The Energy Conservatory, Minneapolis, MN. The DG-2 gauge is designed to measure differential pressures in the range of 0 to 1999 Pascals. The DG-2 gauge measures the pressure difference between the INPUT pressure tap and its corresponding REFERENCE pressure tap. The DG-2 automatically zero's itself during operation.

In order to verify our hypothesis that the stack effect, by way of the elevator shaft, was the main cause for the distribution of fungi above the site of the water event, the DG-2 Pressure Gauge was employed to measure the differences of pressure between the elevator shaft and each individual floor of the building. In addition, the DG-2 was used to measure the effectiveness of the negative air machines used on the work and non-work floors.

Elevator Shaft

While holding the DG-2, standing on the floor outside of the elevator, a plastic tube, connected to the INPUT tap of the DG-2 was inserted into the elevator shaft at the elevator doors. The pressure difference between the elevator shaft and the floor was then read on the DG-2 display. This was repeated on each floor.

Work Floors

Negative air was used to provide and enhance the containment of the work floor from the non-work and cleared floors. To measure the amount of pressure we sought to maintain, the DG-2 was used by measuring the pressure difference between the work floor and the non-work floors. While standing on the work floor, a plastic tube, connected to the INPUT tap was fed into the adjacent non-work and cleared floors thru a small opening in the floor or ceiling. The pressure difference between the adjacent floor and the work floor was then read on the DG-2 display.

In cases, the DG-2 and its operator were located in the REFERENCE area while taking the measurements. This dictated leaving the REFERENCE taps open to the ambient air and attaching the plastic tubing so as to reach the INPUT area to be measured.

Results

Part 1

Airborne Sampling

Table 1 Location	Airborne Fungal Taxa Before Remediation Average Concentration of Sampled Taxa (CFU/m ³)	
2nd floor (N=8)	Penicillium spp.	(9,875)
	Aspergillus spp.	(6,280)
	Ulocladium spp.	(2,100)
	Alternaria spp.	(1,900)
3 rd floor (N=8)	Penicillium spp.	(4,725)
	Cladosporium spp.	(4,380)
	Ulocladium spp.	(600)
4 th floor (N=8)	Penicillium spp.	(4,950)
	Cladosporium spp.	(4,780)
	Pithomyces spp.	(4,575)
5 th floor (N=8)	Penicillium spp.	(3,550)
	Aspergillus niger	(2,500)
	Aspergillus flavus	(1,350)
	Aspergillus nidulans	(1,350)
6 th floor (N=8)	Penicillium spp.	(3,100)
	Aspergillus niger	(2,000)
	Aspergillus flavus	(1,800)
	Aspergillus nidulans	(1,800)
7 th floor (N=8)	Penicillium spp.	(3,200)
	Aspergillus flavus	(2,600)
	Aspergillus niger	(1,900)
8 th floor (N=8)	Penicillium spp.	(3,000)
	Aspergillus flavus	(875)
	Aspergillus niger	(150)
9 th floor (N=8)	Penicillium spp.	(4,250)
	Rhizopus spp.	(4,200)
	Stachybotrys spp.	(90)

10 th floor (N=8)	Penicillium spp.	(4,500)	
	Pithomyces spp.	(4,300)	
11 th floor (N=8)	Penicillium spp.	(1,250)	
	Aspergillus niger	(1,000)	
	Aspergillus flavus	(800)	
	Cladosporium	(800)	
12 th floor	Aspergillus/Penicillium	(3755)	CTS/M ³
	Cladosporium	(640)	CTS/M ³
	Alternaria	(101)	CTS/M ³
	Chaetomium	(51)	CTS/M ³
	Hyphae	(101)	CTS/M ³
13 th floor	Aspergillus/Penicillium	(505)	CTS/M ³
	Cladosporium	(269)	CTS/M ³
	Alternaria	(101)	CTS/M ³
	Basidiospores	(51)	CTS/M ³
	Hyphae	(51)	CTS/M ³
Elevator Shaft Bottom (N=2)	Penicillium	(7,650)	
	Stachybotrys	(160)	
Outdoors (N=4)	Penicillium	(1,000)	
	Aspergillus niger	(800)	
	Epicoccum spp.	(320)	
	Aspergillus spp.	(300)	

Part II

Physical Factors

Opinions on the use of negative pressure, in multiple floor abatement, can vary. Of concern when using negative pressure during abatement projects is first, the quality of “make up air” brought into the work area under negative pressure and second, the effect of the negative air on surrounding non-work areas, including the floors above and below the work area. Negative pressure in the work area can pull in unintended and contaminated air from surrounding non-work areas, the floor above and the floor below. As our abatement proceeded from higher floors to lower floors, unintended airflow from an already cleaned and cleared upper floor was not a concern. Unintended airflow from the contaminated floor below, however, was a concern. Unintended and contaminated air could provide continuous cross contamination to the work area. Depending on the amount of the cross contamination, time and equipment needs for abatement of the work area and air quality restoration may be increased.

At the start of this project, all stairwells and the common ventilation shaft were sealed off on all floors by way of critical barriers. Critical barriers were comprised of double layers of 6ml. fire retardant polyethylene sheeting. As required by the owner’s consultant, a HEPA filtered, negative air machine was placed on the 13th floor to provide positive pressure and thereby, create an air barrier against microbial migration from the lower floors. The positive pressurization of the 13th floor was thought to have a counter effect on potential stack effect and to prevent cross contamination from lower floors. While positive pressure was achieved (7 to 8 Pascals or .025 inches water gauge), the use of this machine did not affect or reduce the “stack effect” in the elevator shaft, as indicated by measurements performed with the digital manometer.

All movements of technicians, equipment, supplies and salvageable items, had to be conducted by using the elevator. Demolition and debris removal were accomplished with exterior chutes into dumpsters. At this time we knew the elevator shaft to be the main culprit in the distribution of *Penicillium*, *Pithomyces* and *Aspergillus* to the upper floors. To reduce ingress of air into the upper floors from the elevator shaft that was under positive pressure, a small airlock chamber was placed immediately outside the elevator doors of the work floors and sealed with spray adhesive and duct tape. The use of negative-pressure negative air machines, as required by the owner's consultant, operating within the work area, had an undesirable impact upon microbial distribution. Through careful attention to the airlock and judicious use of a smoke-generator pencil to make air movement visible, minimal air from the elevator shaft was allowed to enter the work area, with pressure differentials between the airlock and work area fluctuating between 5 and 8 Pascals.

Based on our experience gained early in this project, the best strategy for this multiple floor project was to place the "already cleaned and cleared floor" above the work area under positive pressure to prevent cross contamination from the lower floor (next work area) to the cleared upper floor, reduce unintended air from the stack effect of the elevator shaft into the cleared floor, keep the work floor in a negative pressure relative to the upper floor, and reduce the chance of cross contamination from the floor below the work area. In addition, the use of micro-trap machines in the work floor consistently scrubbed the air and removed bioaerosols and particulate. This procedure would support the arguments of not placing the work area under negative pressure, directly.

The elevator system for entry and exit of materials, equipment and personnel, was also affected by fungal contamination. We decided that access to the elevator shaft was limited. A biocide treatment and fungal removal of all surfaces of the elevator shaft were made periodically, to help reduce any viable fungal load. Periodic treatment of the shaft was done due to the concerns of the stack effect, the transport of bioaerosols from lower to upper, the inability to gain good access for cleaning, and the exposure to the elevator system from the daily work procedures. Air scrubbing machines (micro-traps) and air washing techniques were used during the "controlled demolition phase" with negative air machines employed for several, distinct purposes.

Summary

Fungal contamination was detected on floors above water-damaged floors of a high-rise building for assisted living housing. Our investigation pointed to a potential air movement from the bottom toward the top of the building, "stack effect" via the elevator shaft and staircase. To reduce fungal contamination and cross contamination caused by the "stack effect," we created enclosures on each floor along the elevator shaft and used "micro-trap" machines on each work floor/work area. In addition to the enclosures, we used various patterns of positive/negative air pressurization of work areas versus adjacent areas and upper/lower floors.

This procedure would support the argument of not placing the contaminated areas under negative-air pressure, without considerations of other physical factors, such as "Stack Effect," etc.

Post abatement analytical results validate the success of this procedure and are supportive of the argument of not placing fungal contaminated work areas under direct negative pressure as "routine" or standard procedure. During the fungal remediation project continuous particulate testing and fungal testing were performed as control measures and indicators or potential cross-contamination of the air.

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