Environmental Management of Mould Contamination in a University Hospital

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It is essential to reduce the exposure of highly immunosuppressed in-patients to airborne Aspergillus spores. For the most part, this effort involves greater filtration efficiency, reduction of infiltration of outside air and mitigation of introduced spores by increased air change rates. However, in-hospital proliferation of fungal spores occurs when wetting of organic material occurs. An outbreak of Aspergillus flavus infections in lymphoma-leukaemia patients due to sprayed on cellulose-based fire-proofing material has been reported.\(^1\) as was a sharp increase in airborne penicillin spores due to a leaking sink in a wood cabinet.\(^2\) Aspergillus flavus and Aspergillus fumigatus cases due to wetted particle board housing of cartridge air filters have been reported,\(^3\) while other, less convincing, reports of environmental contamination have appeared.\(^4\) In summary, these reports emphasise that it is important to avoid wet organic debris in the hospital.

Methods

Background

Major construction of the cooling towers on top of the University of Minnesota Hospital and Clinic (UMHC) was under way when an accidentally dropped heavy cylinder penetrated the roof membrane. The hole was not repaired and, during the night of 5 July 1994, about 6cm of rain fell. The roofing was composed of a thick flexible waterproof membrane over four-inch styrofoam insulation, which rested on a concrete slab supported by a contoured metal underform. The incoming water soaked the styrofoam and penetrated the concrete slab through cracks, seeping through to the metal support form. The water flowed in the metal forms and emerging where the forms were penetrated with hangers for mechanical equipment. The water entered 14 patient care locations. Some water saturated ceiling tiles in metal pan holders, some fell to the floor and some accumulated to a depth of 5cm to 10cm behind paper-backed dry wall gypsum board.

Environmental Sampling

From the roof area and the rainfall, it was estimated that about 4,000 litres of water penetrated the slab space, with about 2,000 litres entering the patient care spaces. Moisture in dry wall was detected by application of an electronic wet test meter to the room walls; >15% moisture content was considered abnormal. Air samples were collected on inhibitory mould agar (IMA) using a high-volume (700 litres per minute) slit impactor. Swab and bulk samples were collected and plated on the IMA. The samples were incubated at 25ºC and 35ºC for up to seven days for evaluation. Horizontal surface contact media plates were used with IMA and were incubated at 35ºC. Identification of pathogens was to the genus level while Aspergilli were speculated. Samples were collected at designated intervals during the water damage, demolition/remediation, decontamination and clean-up processes.

Ventilation Control

The contaminated area was ventilation-balanced to reduce the supply air volume in order to create a negative pressure with airflow into the contaminated space. The connecting doors were tape-sealed and signed for no admittance. The area was checked daily for airflow direction using a smoke stick. Portable high-efficiency particulate air (HEPA) filters were placed in the corridors outside of the areas being remediated. The water-damaged areas were identified during the demolition/ remediation processes. Some water saturated ceiling tiles in metal pan holders, some fell to the floor and some accumulated to a depth of 5cm to 10cm behind paper-backed dry wall gypsum board.

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building ventilation recirculated spores released during the project clean-up.

**Decontamination**

The contaminated areas with open walls were decontaminated using a 1:9 dilution of a copper-8-quinolinolate compound using a pressurised spray pump. Structural steel insulation had copper-8-quinolinolate incorporated at 200 parts per million during initial construction. Once decontamination was finished, the walls and ceilings were closed with standard wall-finish materials.

**Clean-up**

A modified clean room clean-up technique was used to remove residual spores from the patient care environment after repair/remediation. Trisodium phosphate detergent (1:200 water:crystal dilution) was used to remove the surface dirt. Physical removal from vertical and horizontal surfaces was accomplished using disposable cleaning items. The surfaces had to be cleaned twice with frequent disposal of contaminated cleaning cloths. Before final area preparation was completed, a 1:10 dilution of 10% bleach solution was used to wipe all vertical and horizontal surfaces. Ceilings were initially cleaned back and front using HEPA-filtered vacuum cleaning. All non-egress doors were taped shut after cleaning to help assure contamination control.

**Results**

**Microbial Evaluation of Water-damaged Area**

Wet test readings of wall board revealed 14 scattered (because of unpredictable patterns of horizontal water dispersion in the subslab metal supports) rooms with walls having excess moisture. Routine room and corridor air samples taken during August 1994 had an average of 7.3 and 3.7 *Aspergillus fumigatus* cfu/m³, respectively (see Figure 1). Removed wall board revealed abundant visible mould growth on the internal paper surfaces up to a discreet waterline where water had collected behind the wall board. Bulk samples were in excess of 10% per 5cfu per gram of wall board and >10% per 6cfu/cm². *Aspergillus fumigatus* was the predominant filamentous fungus in eight of 12 samples taken. All areas testing positive with the west test device had mould growth on the backside of the gypsum board. Control, wet test negative wall board yielded only rare *Aspergillus fumigatus*.

**Air-sample Analysis of the Contaminated Space**

Figure 1 displays the level of airborne contamination during the various sampling periods during this evaluation. The maximum average sample concentration was 78cfu/m³ total thermo-tolerant fungi during the week of 22 September 1994. The high levels of airborne fungal contamination were associated with the physical removal of visible mould on water-damaged gypsum board.

Normal average levels in the UMHC were derived from six years of on-going air sampling. The normal level of *Aspergillus fumigatus* on patient care wards is <1.0cfu per m³ (see Table 1). The reaction to these normal levels was immediate and directed towards removing the susceptible patient population and sealing the area off from the large population of immune-compromised patients in the UMHC. The 40-bed station was closed to patients and most other traffic.

**Surface Sampling**

Rodac plates in September 1994 had seven of 14 plates with too numerous to count (>300cfu/plate) fungi with *Aspergillus fumigatus* at >45% of the microbes recovered. Ten of the 14 plates were positive for *Aspergillus fumigatus*. With cleaning, the vertical surfaces had no fungal contamination and the horizontal surfaces found two of eight samples positive. A second cleaning demonstrated no *Aspergillus fumigatus* recovered from 37 samples. The figure is a time-period histogram for the respective water damage, demolition, remediation and clean-up air-sampling results. The absence of *Aspergillus fumigatus* in the post-cleaning phase assured that the contaminant was removed.

**Discussion**

Abundant fungal bloom was observed with extensive

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Mould Contamination

water damage in a critical care hospital. Previous experience with nosocomial aspergillosis caused a response to contain the contamination. Background hospital sampling from occupancy in April 1986 provides average airborne cfu data from 385 PCU samples. The increase of Aspergillus fumigatus particularly prompted investigation, which resulted in vacating of patients and isolating the area from the rest of the hospital. The ventilation adjustment and traffic control helped to contain construction-released fungal spores within the contaminated area. Portable filters in the clean-up zone helped to capture and dilute the released microbes. Comparison sampling in the contaminated area and adjacent PCUs provided assurance that the Aspergillus fumigatus were not migrating out of the ward. The use of surface contact plates documented the clean-up from very contaminated to no Aspergillus fumigatus detected on horizontal and vertical surfaces.

Water damage in buildings occurs more frequently than we are aware of, especially during building construction. Building construction is susceptible to water damage during storms if the exterior of the building is compromised or while new plumbing and fire management systems are being tested. Otherwise, water damage can occur due to high humidity or roof, plumbing and window leaks. Arnow, et al. had extensive experience with water damage of organic substrates and fungal proliferation, but did not describe the clean-up methods. Few descriptions exist for proper clean-up in critical hospital environments.

In one study, copper-8-quinolinolate was used to decontaminate the water-damaged area. In another, a bleach dilution was used for decontamination before physical removal in a child care centre, which was verified with environmental sampling. Both Opal and Rhame utilised portable HEPA recirculating filters to enhance the ventilation for the protected areas. Negative-pressure air balance control is common for asbestos containment; such methods can be used to

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Table 1: University of Minnesota Hospital and Clinic Baseline Airborne Filamentous Fungi Average Concentrations (cfu/m³)

<table>
<thead>
<tr>
<th>Incubation temperature</th>
<th>Location</th>
<th>N⁴</th>
<th>25°C</th>
<th>37°C</th>
<th>A. fumigatus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Outside⁵</td>
<td>203</td>
<td>639</td>
<td>66</td>
<td>4.9</td>
</tr>
<tr>
<td></td>
<td>Reference⁶</td>
<td>223</td>
<td>290</td>
<td>27</td>
<td>4.1</td>
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<tr>
<td></td>
<td>Foyer⁷</td>
<td>109</td>
<td>148</td>
<td>22</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td>Wards⁸</td>
<td>385</td>
<td>49</td>
<td>7.4</td>
<td>0.42</td>
</tr>
<tr>
<td></td>
<td>BMT⁹</td>
<td>168</td>
<td>44</td>
<td>5.8</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>Therapeutic rad.¹⁰</td>
<td>124</td>
<td>50</td>
<td>7.8</td>
<td>1.1</td>
</tr>
</tbody>
</table>

Key: ¹ = number of determinations; ² = 30-second samples or 350 litres; ³ = two-minute samples or 1,400 litres.

Table 2: Horizontal Surface Sampling (September–December 1994)

<table>
<thead>
<tr>
<th>Average cfu per plate</th>
<th>Date</th>
<th>No. of plates</th>
<th>Total</th>
<th>A. fumigatus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Controls</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td></td>
</tr>
<tr>
<td>15 September</td>
<td>8</td>
<td>&gt;265</td>
<td>155</td>
<td></td>
</tr>
<tr>
<td>27 September</td>
<td>8</td>
<td>65</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>9 October</td>
<td>8</td>
<td>9</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>4 November</td>
<td>4</td>
<td>27</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>18 November</td>
<td>4</td>
<td>12</td>
<td>1</td>
<td></td>
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<tr>
<td>2 December</td>
<td>0</td>
<td>&lt;1</td>
<td>0</td>
<td></td>
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<tr>
<td>7 December</td>
<td>4</td>
<td>&lt;1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>8 December</td>
<td>6</td>
<td>1.3</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>14 December</td>
<td>7</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>15 December</td>
<td>7</td>
<td>1.2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>20 December</td>
<td>6</td>
<td>1</td>
<td>0</td>
<td></td>
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<td>22 December</td>
<td>7</td>
<td>1.3</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Another study showed that asbestos-like containment methods for providing barrier management and ventilation airflow into the construction of a bone marrow unit was successful in containing construction aerosols. The author’s experience used portable filters, copper-8-quinolinolate decontamination and modified clean-room clean-up to ensure satisfactory results when removing opportunistic Aspergillus fumigatus spores from a contaminated area. Top-downward cleaning procedures were required in the contaminated rooms, with the ceilings and floors HEPA-filter vacuum cleaned. The regular hospital cleaning staff were used to clean the rooms in a standard manner before occupancy. The final occupancy cleaning occurred some months after the environmental sampling certification of the contamination removal. On-going air-sample surveillance shows satisfactory air quality after occupancy. This water damage experience demonstrates the removal of heavy contamination, which was allowed to remain wet for about two weeks before clean-up was initiated.

It was demonstrated in a laboratory that fungi can proliferate into heavy sporulation after three days in ideal conditions. If water leaks occur in hospitals near critical care areas, the water damage must be identified and removed. Otherwise, prolific mould growth can occur and tedious decontamination clean-up must be provided in order to protect susceptible patients subsequently occupying the hospital area. The wet test meter is an excellent diagnostic device that helps to identify wet areas. Such definition of the wet area allows for immediate opening of walls to allow drying before mould sporulation. Since the leak in July 1994, five additional water leak incidents have been successfully identified and dried. In each situation, walls were opened and/or dehumidification provided to enhance drying before mould growth.

This experience demonstrated that proactive analysis of a critical hospital can prevent potential problems in a sensitive patient care environment. Known nosocomial filamentous fungal disease was not experienced due to this water damage incident. Environmental sampling of both air and surfaces proved valuable for detecting and ensuring the removal of the potentially hazardous agent from the critical patient care environment. Administrative action brought on by consultation with the hospital epidemiologist and bed allocation administrators averted potential nosocomial aspergillosis in patients who may have been housed in that particular PCU.

**Conclusion**

This hospital water damage incident can serve as a guide for establishing water damage control in hospitals. Disturbance of such water-damaged areas can create large bursts of transient spore cloud, which can be hazardous to compromised patients. Special ventilation should be provided to supplement standard hospital ventilation practice to prevent Aspergillus-induced pneumonia.

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