Fungal Remediation and Protective Antimicrobial Treatment Of a Grossly Contaminated Ten Story Hospital

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Abstract

After over five years of planning and construction and two months after opening, Hospital Sultan Ismail was infested with potentially deadly fungus. The areas of the extensive visible mold growth *(Dominant Species: Aspergillus fumigatus)* were widespread throughout the entire ten storey hospital which has 704 beds and 3004 rooms.

A focused environmental investigation was undertaken for microbial growth within the building using organoleptic observations, records review, and microbial sampling techniques along with environmental condition measurements of temperatures, relative humidity, carbon monoxide, carbon dioxide, and laser particle measured particles. Infrared scans of all building areas were done to determine areas of moisture concentration within the structural materials and spaces.
These studies uncovered abnormally favorable conditions for microbial growth and revealed moderate to high levels of fungi on interior surfaces and air sampling results showed >1000CFU/m^3 in most areas.

The mycological goals of the building restoration project were to reduce microbial reservoirs and control of fungi on all exposed surfaces to the lowest attainable level. All visibly colonized materials in the building were discarded and all fine dust on interior surfaces was removed by vacuuming and/or damp wiping. A chemically bonded durable broad spectrum long-lasting organosilane antimicrobial treatment (ÆGIS™), 3-trimethoxysilylpropyldimethyloctadecyl ammonium chloride, was selected to treat all building and furnishing surfaces during restoration.

Testing of the facility at five months following restoration showed 12% of the indoor environment to be free of airborne fungi, 53% with <100 CFU/m^3 (colony forming units per cubic meter) of air, and 35% with over 100 - 200 CFU/m^3. This represented an on-average reduction from the 307 sampling sites of 88% or almost nine times.

Introduction

Since the mid-1800's there has been a growing concern about adverse health effects of fungal contamination on hospital occupants, patients, visitors, and staff. Then, as now, the morbidity and mortality resulting from microbial exposure encouraged the advancement of general disinfection, aseptic technique, and a variety of practices and procedures to control occupant exposure to exogenous microflora. The basic principles of infection control established by Pasteur, Lister, Semmelweiss, and others provided focus on infective organism dose and virulence and host susceptibility. Most practical avoidance, prevention, and remediation practices have evolved around dose control. This is an important principle as one looks at fungal contamination and control. Fungi are potent pollutants causing deterioration, staining, musty odors, and health problems from simple discomfort, irritation, allergenic sensitization, toxic response, infectious disease, illness, and death all associated with growth of fungi in buildings.[1, 2, 3 & 4]

Control of microorganisms in indoor environments has traditionally focused on source control, ventilation, and air cleaning. Disinfecting compounds are often toxic. Harmful substances interfere with vital body processes by destroying enzymes, blocking oxidation, restricting the functions of various organs and initiate cellular changes and mutations. Ordinary cleaning can be effective in places that can be easily reached but the hard-to-reach places and the "out-of-sight out-of-mind" places often become reservoirs and amplification sites for contaminating microbes. Cleaning also has limitations in its effectiveness and it is often expensive. This concern has encouraged researchers to look for other solutions.

Researchers in 1969 discovered a novel antimicrobial, using an alkoxysilane-coupling agent reacted to a quaternized amine. Plueddemann was able to covalently link this and related reactive silane chemistries directly to surface molecules. The bound monomers then reacted with each other to form a cross-linked polymer of extremely high molecular weight, thereby producing an essentially permanent antimicrobial surface. The physical interruption of the cell membranes of one celled organisms by this reacted nano-polymer durably bonded to surfaces has was well described. [5, 6, 7, 8 & 9]

The modification of interior surfaces with a bound antimicrobial agent could prevent the development of microbial reservoirs in a building and the easy recolonization of cleaned or disinfected surfaces. The destruction of airborne microorganisms upon contact with antimicrobial surfaces would further reduce human exposure potential, producing an environment with lowered risk of allergenic, infective, or toxigenic consequences for building occupants.

The present study was conducted to determine the level of microbial control possible from the comprehensive use of the ÆGIS organofunctional silane quaternary ammonium compound in a severely contaminated building and to assess the duration of effective control.

Materials and Methods

Background

This study was done over a five-month period from November 2005 through March 2006 at the Hospital Sultan Ismail located in Johor, Malaysia. On September 25, 2004 the Ministry of Health closed the hospital because of the potentially deadly fungal infestation which was present throughout the hospital. The remediation process and protective ÆGIS treatment began in March 2005 and was completed in four months.

Microbiological Sampling

Airborne fungal samples were obtained from 307 sites using an Andersen air sampler loaded with a Petri-dish containing 20 ml of Potato dextrose agar (PDA) at a constant sampling rate of 28.3 l/min. (liters per minute). Air was impacted on the plates for one to four minutes at each site. Exposed plates were incubated at room temperature and examined over a five day period. The number of CFU/m^3 was calculated from the number of CFU's counted and the collected air volumes. Samples were collected at designated intervals during pre and post treatment.

Decontamination

The contaminated areas with open walls were decontaminated using a 20% Ox Bio$^+$ solution. After decontamination residual spores and visible contamination were removed by physical removal from vertical and horizontal surfaces using disposable cleaning items. The surfaces had to be cleaned twice with frequent disposal of contaminated cleaning cloths. Ceilings were initially cleaned back and front using a HEPA-filtered vacuum. All non-egress doors were taped

shut after cleaning to help assure contamination control. Workers wore appropriate personal protection gear treated with the ÆGIS treatment for antimicrobial protection.

Surface Modification

All accessible interior surfaces (including ceilings, walls, above ceiling space, furnishings, elevator shafts, mechanical and electrical chases) were treated with the 3-trimethoxysilylpropyldimethyloctadecyl ammonium chloride (ÆGIS™ Antimicrobial) [6] in water in accordance with the manufacturer's application specifications. The applications were randomly tested for uniformity and penetration throughout the treatment process using analytical methods appropriate for the active ingredient.

Results

The results of the samplings are presented in Table 1. Pre-treatment retrievals were in a range of 35 – 4730 CFU/m^3 and the average sample concentration was 791.4 CFU/m^3 in the March 2005 sample set. The high level of airborne fungal contamination was associated with the growth of visible mould verified by surface samples and identifications. Intrusion of fungi from the outdoor environment was noted but the dominant and pervasive *Aspergillus fumigatus* was not part of this population.

Location		Pre- treatment CFU/m^3	2005		2006		
			Nov	Dec	Jan	Feb	March
Total Building	Average Sites	791.4 307	48.1 307	56.4 307	72.2 307	101.4 307	96.6 307
1 st Floor	Average Sites	367.4 35	65.8 35	75.1 35	77.1 35	99.3 35	117.9 35
2 nd Floor	Average Sites	533 38	55.1 38	71 38	54.5 38	111.2 38	111.8 38
3rd Floor	Average Sites	715.7 42	65.8 42	80.3 42	47.2 42	109.2 42	111.3 42
4 thFloor	Average Sites	502.8 42	79.4 42	59 42	89.6 42	91.4 42	102.4 42
5th Floor	Average Sites	424.1 42	46.3 42	42.1 42	58.1 42	93 42	95.6 42
6th Floor	Average Sites	1978.2 36	58.1 36	45 36	97.7 36	94.9 36	70.1 36
7th Floor	Average Sites	738.5 24	32.3 24	29.3 24	66.5 24	90.3 24	121.6 24
8th Floor	Average Sites	1336.8 24	30.8 24	41.1 24	65 24	96.3 24	87.3 24
9th Floor	Average Sites	695 12	20.6 12	62.1 12	95 12	127.5 12	74 12
10th Floor	Average Sites	622.1 12	26.5 12	59.1 12	71 12	100.7 12	74 12

Table 1. Concentration of airborne fungi (CFU/m^3) at Hospital Sultan Ismail, Johor, Malaysia – Pre- and Post-ÆGIS Treatment.

Post-ÆGIS treatment sampling during the first month following restoration of the building produced an average of 48 CFU/m^3 at 307 sites. Retrievals were in a range of 0-178 CFU/m^3. Of the 307 sample sites, 24% had 0 CFU/m^3. *Figure 1* displays the level of reduction of airborne contamination on each floor during this evaluation period.

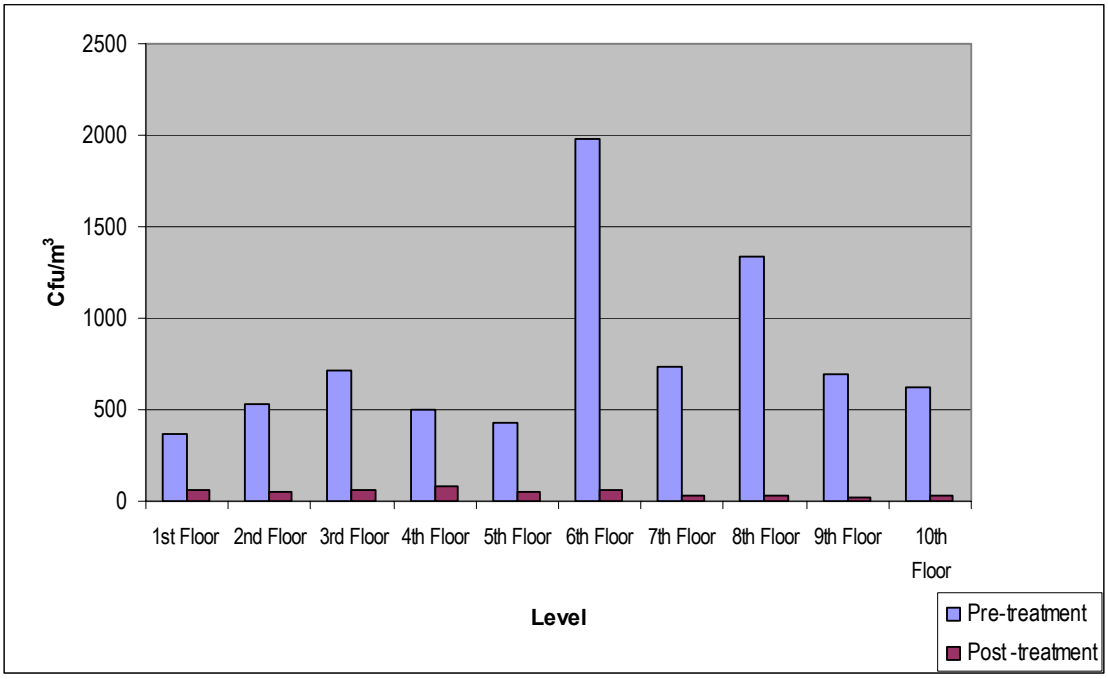

Figure 1: Reduction in microbial air retrievals after ÆGIS treatment. Hospital Sultan Ismail, Johor, Malaysia.

Subsequent routine air sampling was performed at one month intervals for another four months from December 2005 to March 2006. These samples had an average of 56.4, 72.2 101.4 and 96.6 CFU/m3 respectively (Fig. 2). The samplings produced retrievals in a range of 0-178 CFU/m^3.

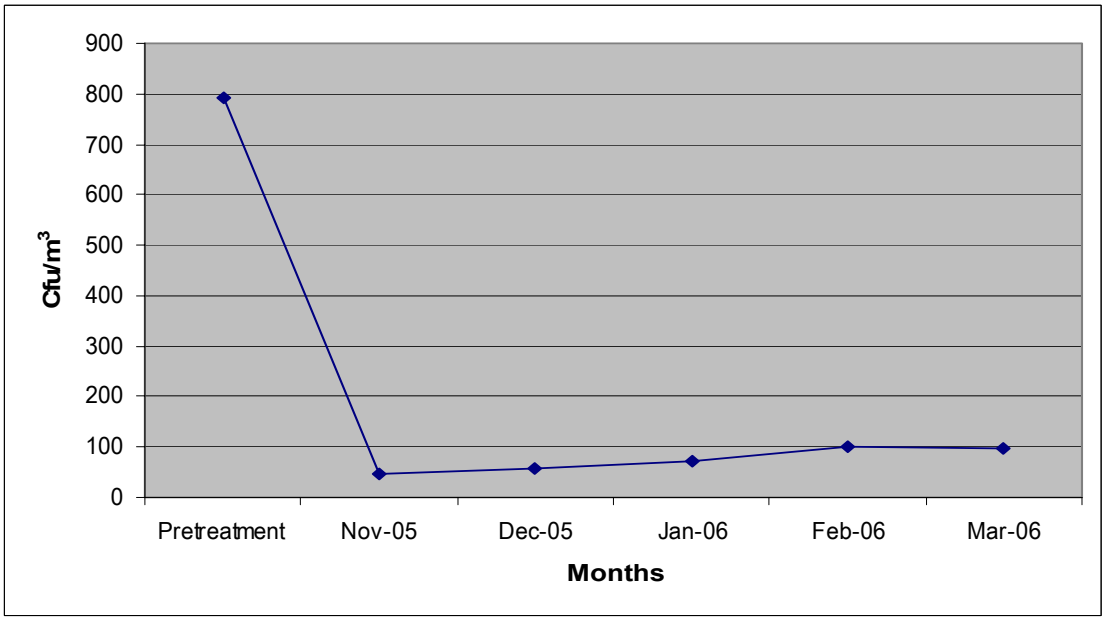

Figure 2: Retrieval averages of pre and post-ÆGIS treatment samplings in the building. Hospital Sultan Ismail, Johor. Malaysia.

Swab sampling in March 2005 showed >300cfu/cm^2 fungi with *Aspergillus fumigatus.* Fogging with Ox Bio+ followed by application of ÆGIS™ demonstrated no *Aspergillus*

fumigatus recovered from the horizontal and vertical surfaces. The absence of *Aspergillus fumigatus* in the post-cleaning phase assured that the contaminant was removed.

Discussion

The microbial colonization of interior surfaces in buildings is well known when extensive and often normal water damage occurs during the construction period or during the use of the building. Building construction materials are susceptible to water damage and mould growth during storms when the exterior of the building is compromised or while new plumbing and fire management systems are being tested. Additionally, water damage can occur due to high humidity or roof, plumbing and window leaks. These water events are often hidden inside the building construction and easily colonized by microorganisms. These microbial reservoirs can be significant sources of bioaerosol emissions in so-called mould problem houses and buildings.[10, 11 & 12]

Several studies have implicated airborne microbial contaminants in the development of Building Related Illnesses and Sick Building Syndrome and are life and death hazards to compromised patients.[13, 14, 15 & 16]

Rhame et al[8] have shown a direct correlation between the concentration of airborne Aspergillus spores in hospital air and the incidence of aspergilliosis among immunosuppressed patients; Arnow et al[9] report "our findings strongly suggest that the inanimate hospital environment is a major determinant of the risk of endemic or epidemic nosocomial aspergilliosis".

All traditional disinfectant products have vapor pressure and water solubility properties that allow for migration. This magnifies occupant exposure concerns and the potential for sub-lethal doses to which microbes could adapt. The duration of antimicrobial activity of traditional disinfectants is also relatively short (ranging from a few minutes to several days) unless incorporated within a substrate with slow-release characteristics. Although most disinfectant formulations appear to possess increased activity against specific classes of microorganisms, this selectivity precludes broad-spectrum control. Also, many disinfectant active ingredients have been shown to give rise to adapted microbial population. This is unacceptable in almost all end-uses.

Environmental sampling of both air and surfaces has proved valuable for detecting and ensuring the removal of the potentially hazardous agents from critical and normal environments and was used as the prime indicator in this study.

During this study the normal housekeeping staff was used to clean the rooms in a standard manner before occupancy. The final occupancy cleaning occurred some months after the certification of the original remediation and contamination removal. On-going air-sample surveillance has shown satisfactory air quality as full occupancy of the building is being implemented.

The relative humidity, temperature, carbon monoxide, carbon dioxide, particle distribution, and other environmental measurements were used to decide clearance approval and help suggest air handling and cleaning protocol adjustments. During this study the building was not under ASHRAE (American Society of Heating, Refrigeration, and Air conditioning Engineers) recommended levels of relative humidity and temperature compliance was highly variable throughout the building. In all circumstances the indoor and outdoor environmental conditions favored the growth of fungi.

Conclusions

With the continuing increase in the number of severely immunocompromised patients, hospitals and all indoor public spaces are faced with being the source of fungi that cause

problems of invasive aspergilliosis and other opportunistic fungal infections. Since treatments of these infections are difficult and outcome is often fatal, preventive measures are of major importance in the control of invasive filamentous fungal infections. Further to this, fungi produce allergenic and irritational spores and a wide variety of toxigenic chemicals including known human carcinogens. On the non-medical side of impact, fungi cause deterioration of building materials and furnishings, musty discomforting odors, and unsightly stains that affect the usefulness and life of affected materials.

Data from this study indicate that surfaces modified with a reactive-silane antimicrobial (ÆGIS Treatment) provide substantive reduction of airborne microbial concentrations even under extreme environmental conditions that favor fungal growth. Sustained control of microbial levels has been demonstrated through this first five months of the ongoing study providing a cleaner, healthier environment of care for this specialty health care facility. During this study period the previously heavy visible and widespread growth on surfaces was eliminated.

When viewed collectively, the safety, efficacy, and durability of the ÆGIS technology and application procedures has provided a unique way for the control of risks to building materials and occupants associated with microbial contamination in buildings without continuous care of normal and hard to reach surfaces.

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