RISK ASSESSMENT OF MOULD EXPOSURE IN MINE SITE ACCOMODATION BUILDINGS

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ABSTRACT

The recent mining boom in the Northwest of Western Australia had lead to the region experiencing some of the highest rates of growth anywhere in the world. This recent increase in mining activity was in the wake of 10-15 years of lesser activity that resulted in poor maintenance and low grade facility upgrades. The primary restriction to growth industries in this region is in providing accommodation for the massive influx of workers. This investigation was a targeted assessment of the health risk of occupants to mould exposure in mine site accommodation buildings.

The buildings are colloquially known as "Singlemens Quarters" or "Dongas" and were located in the Pilbara Region of North-West Australia. Initial inspections were initiated by a flooding event; however, the investigation of the affected rooms identified several areas of existing mould damage. The main causes of the mould damage were refurbishments of wet bathroom areas into accommodation units and condensation from constant air-conditioning, which resulted in interior finishing's & materials being below the dew point temperature. Extensive

visible mould growth was manifest throughout the accommodation buildings. A detailed scope of works provided step by step instructions for workers with the aim of re-instating the mould affected accommodation to a normal or habitable condition. This study highlighted the need for a methodical and thorough process when assessing risk of mould exposure and in mould mitigation and mould remediation processes. The proper appropriation of resources in this project also established the financial and environmental benefits of this approach.

INTRODUCTION

When it comes to occupational health and safety obligations, there are various regulations that employers are required to carry out to remove or reduce risk in the workplace. These risk management and assessment techniques utilise a process approach whereby steps are set out, and must be complied with to remove or reduce the risk (Toohey *et al*., 2005). A more recent approach towards Occupational health and safety utilises a general and holistic approach towards all hazards, and targets not only hazard-specific regulations but also those not highlighted by particular standards or regulations, thus encompassing a more holistic approach to the health, safety and welfare of workers. Once such area that requires further research and attention is in the area of indoor air quality and in particular indoor fungal levels in worker's accommodation.

There is little scientific research on the effectiveness of assessment procedures on the risk to mould exposure in mining accommodation buildings. The increase in mining activities in the Pilbara Region of North West Australia has significantly increased the demand for accommodation in the region. This has in turn put significant pressures on existing accommodations and infrastructure with management of personnel including "hot bed swapping".

This case study investigated the accommodation buildings of a major mining site in Northwest Western Australia. The pressure and demand for accommodation has lead to existing accommodation blocks that were 50-60 years old being renovated or retrofitted to cater for the requirements of a modern workforce. HVAC systems comprising of either ducted or split air systems were being installed in rooms to counteract the prevailing extreme heat climate of the region.

Climate

The prevailing climate in the North West of WA consists of high humidity (up to 85-95%) and temperatures constantly between 35-45 degrees Celsius during summer. The combination of air conditioning, high humidity and high outdoor temperatures creates ideal conditions for dew point problems to occur in the buildings. This is especially the case in buildings that were retrofitted with AC units without accounting for the poor insulation design of the older style buildings.

Mould Assessment

There are no Australian Standards for the assessment of mould damage. Further more, there are no standardised methods developed for measuring risks due to mould spores and the difficulty due to the unique conditions present at each location (Chapman, 2006). An industry reviewed guideline "The Australian Mould Guideline 2005" has been published by the Authors and sets out inspection procedures and remediation techniques (AMG-1, 2005). However, the current industry standard for the assessment of mould exposure in indoor buildings often relies on a cursory visual inspection by poorly trained inspectors. Even where sampling is performed, there is little attention paid to the methods and analysis resulting in poor results that provide little information on the true extent of the exposure to mould (Kopp & Fillhart, 2004). Furthermore, the extent to which hidden mould growth contributes to airborne mould concentrations is not clearly understood and requires further investigation (Hagmolen *et al.,* 2007; Munir & Bjorksten, 1997).

In order to asses mould exposure and to reveal problems such as hidden mould growth, a combination of airborne, surface and material sampling is required including thorough inspection of all building cavities and conducting structural moisture and dew point testing.

The aim of this investigation was to conduct a complete assessment of the risk of indoor mould exposure in an accommodation building. The comprehensiveness of the risk assessment can only be assured when using a combination of visual inspection, airborne sampling, and surface sampling and materials sampling as well as destructive and forensic inspection of all building cavities.

METHODS

Inspection

A standardised visual inspection was conducted in Accommodation Buildings. The buildings were 2 storeys with rooms on either side of a central corridor. The long axis of the buildings were oriented East-West. Construction materials were double brick cavity, concrete slab and clay roofing tiles. Outdoor windows and doors were aluminium framed and single glazed. The rooms were air-conditioned by individual wall mounted split system AC units with a central chiller plant. Fresh air and ventilation was only available by opening windows to allow outdoor air in, which was discouraged by facilities management.

Mould inspections included both affected and non-affected rooms, their contents, the roof space and a survey of occupants and building maintenance and managers was conducted to ascertain the potential problem/s in the building. Subsequent inspections including destructive sampling, moisture and dew point testing was conducted to investigate the potential for hidden mould and underlying structural moisture problems. This includes the use of borescope (Olympus, USA; Testo, USA), and a moisture meter (Protimeter MMS, GE Protimeter plc, Marlow, UK)).

Mould Sampling

- Viable Airborne Mould - Andersen Type N6 400 hole sampler @ 28.3 litres/min for 2 minutes with 90mm plates and 2% MAE nutrient agar (SCK BioStage, UK);
- Total Airborne Spores - Zefon (USA) Air-O-Cell cassette & BioPump, 5-10 minutes at 15 l/minute
- Viable Surface Mould - 55mm surface press plate filled with 2% MAE nutrient agar;
- Surface Spores - Tape Lift-Off –Either Zefon BioTape or Samples taken with adhesive tape, stained with lactophenol cotton blue and observed under microscope (x 400); samples are held in storage for a min of 2 years;
- Material Samples - Materials are sampled by using a tape lift-off method or by plating out the material onto the nutrient media listed below
- Incubation Conditions minimum of 96 hrs at 20 ± 2 °C;
- Nutrient Media Mould (MAE) 2% malt extract agar (MAE)

RESULTS

Initial Inspection Results

The initial inspection of the accommodation buildings revealed extensive visible mould growth throughout the gyprock ceiling and walls in the accommodation rooms. There was significant condensation and dew point problems on bulkheads and in the built in wardrobes caused by a combination of incorrect setting of air conditioning systems, lack of insulation and wide temperature range between the outside air and dead air spaces. The split system air conditioners were visibly mouldy with cooling coils, fins and fan cowling showing extensive mould growth.

Figure 1 Grade 4 Mould contamination on ceilings

Figure 2 Water staining insides of built in wardrobes

Figure 3 Mould Contaminated air conditioning fins

Typical Airborne Fungal Results

Figure 4 shows typical airborne sampling results for one of the buildings with moderately high to extremely high concentrations of airborne mould in the rooms. The Indoor Average for all buildings was 2170 CFU/m^3 and was rated at very high. This was higher than the Outdoor Air concentrations, which was also above the WHO guidelines (indoor concentrations to be less than half the outdoor air concentrations) (WHO, 1993; Cheong et al, 2004 & 2005). Table 1 shows the typical speciation for one of the buildings and reveals that extremely high concentrations of airborne mould were found in Room 5. The comparison of species between the indoors and the outdoors shows that *Cladosporium*, *Penicillium, Alternaria, Acremonium* and yeast species were higher indoors than in the outdoor air. This gives a clear indication that these fungi were growing indoors.

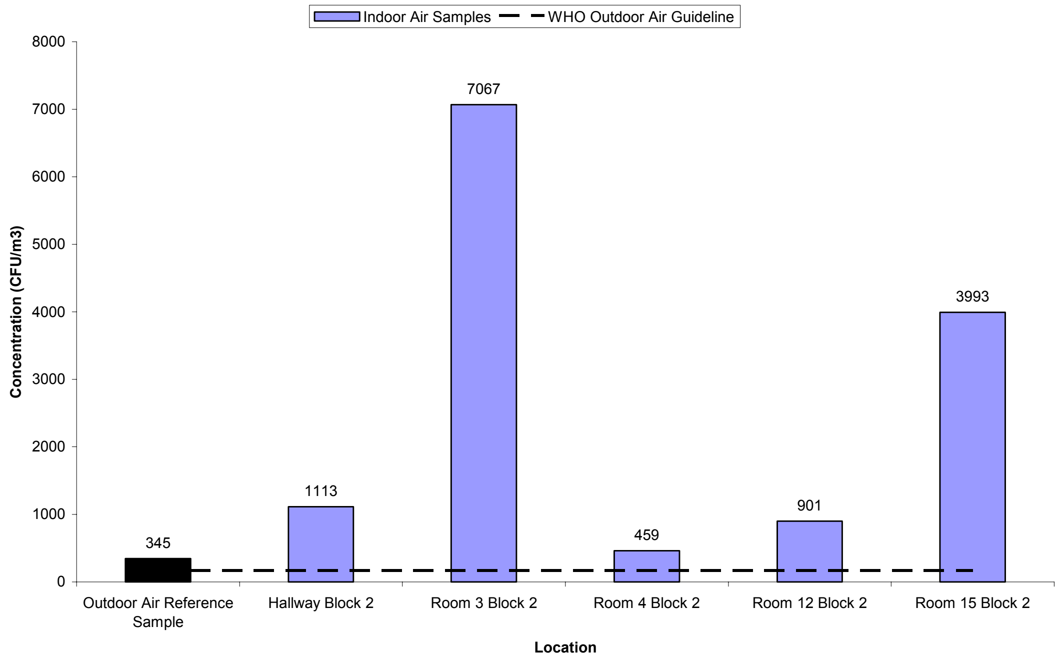

Figure 4 Typical Airborne Fungal Concentrations

Table 1 Typical Airborne Fungal Species Mixture

Fungal Species	Outdoor Air Reference	Hallway 1st floor	Room 5 1st floor	Room 11 1st floor	Room 16 1st floor	Hallway 2nd Floor	Room 36 2nd Floor
Cladosporium sp.	▣	◘	×	◘	◘	□	▣
Aspergillus sp.	⊡	□	×	×	×	×	×
Penicillium sp.	⊡	◘	■	◘	■	⊡	▣
Alternaria sp.	□	⊡	×	⊡	□	□	×
Yeast sp.	□	⊡	×	▣	⊡	⊡	⊡
Acremonium sp.	×	⊡	×	□	×	□	⊡
Fusarium sp.	×	×	×	×	⊡	×	×
Nigrospora sp.	×	⊡	×	×	×	×	×
Sterile Mycelia	×	□	×	×	×	×	×
Zygomycetes	×	×	⊡	×	×	×	×

Location

Legend

Symbol	×	□	⊡	▣	◘	■
CFU/Plate	<1	<6	<18	<30	<60	>150
Rating	Below Detection Level	Several Colonies	Established Species	Moderate Concentrations	High Concentrations	Dominant Species

Surface Fungal Results

Figure 5 shows the typical surface mould results with extremely high concentrations detected on the ceiling panel and desk in Room 5, Flooring under the carpet and on the wardrobe in Room 11, Wardrobe in room 16, and Wardrobe in Room 31. Table 2 shows that the main surface species were *Penicillium*, *Cladosporium, Alternaria, Aspergillus, Fusarium* and *Zygomycetes.* These are typical "Water-Loving" fungi. Areas of greatest concern where Extremely High concentrations of a single species were detected include the underside of the ceiling panel and desk in Room 5, Floor and wardrobe in Room 11, and the Wardrobes in Room 16 and 31. This indicates that fungal growth was occurring on these surfaces. These results clearly indicate that the contaminated surfaces require cleaning to remove mould growth.

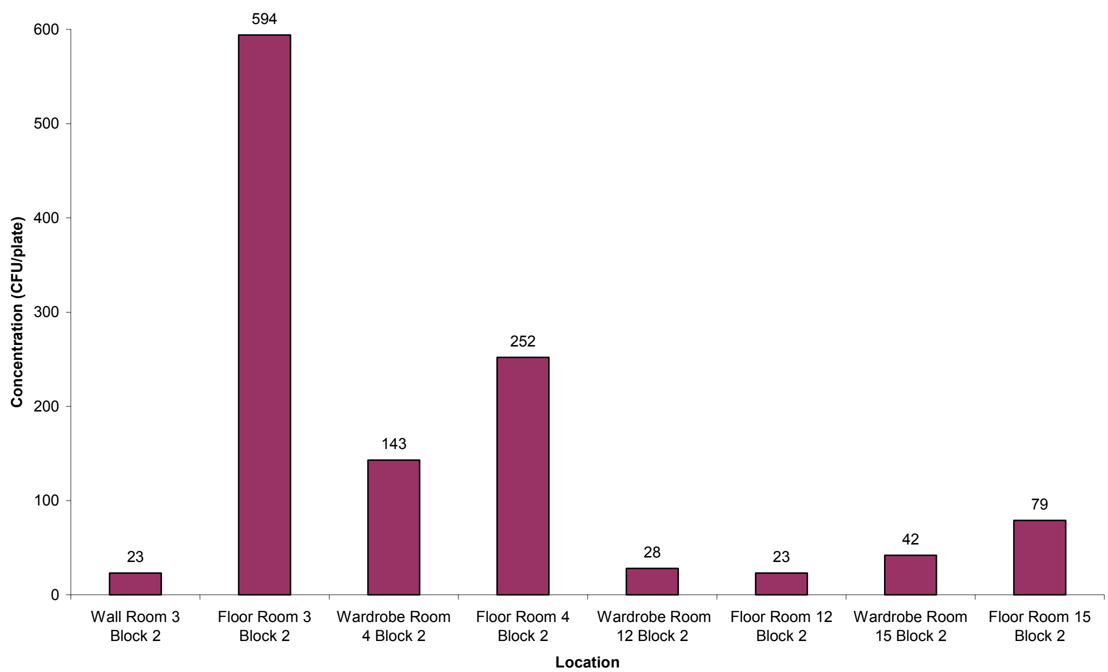

Figure 5 Typical Surface Fungal Concentrations

Table 2 Typical Surface Fungal Species Mixture

Location	*Penicillium sp.*	*Alternaria sp.*	*Aspergillus sp.*	*Cladosporium sp.*	*Fusarium sp.*	*Zygomycetes*
Underside Ceiling Panel Room 5 Block 3	■	×	×	×	×	×
Desk Room 5 Block 3	×	×	×	■	×	■
Floor under carpet Room 11 Block 3	■	×	×	×	×	×
Wardrobe Room 11 Block 3	■	×	×	×	×	×
Wardrobe Room 16 Block 3	■	×	×	×	×	×
Wardrobe Room 31 Block 3	×	×	×	■	×	×
Desk Room 16 Block 3	◘	×	□	×	□	×
Wall Room 31 Block 3	▣	□	×	×	□	×
Floor Room 31 Block 3	⊡	□	×	⊡	×	×
Wall Room 11 Block 3	⊡	×	×	×	×	×
Wall Room 16 Block 3	⊡	×	□	×	□	×
Carpet Room 11 Block 3	□	×	□	×	×	×
Fridge Room 5 Block 3	×	×	×	×	×	×

Fungal Species

Legend

Symbol	×	□	⊡	▣	◘	■
CFU/Plate	<1	<6	<18	<30	<60	>150
Rating	Below Detection Level	Several Colonies	Established Species	Moderate Concentrations	High Concentrations	Dominant Species

Air-Conditioners

Surface sampling of the air conditioners tested showed extremely high (> 25,000 CFU/cm^2) surface concentrations of fungal (mould) spores. Extremely High concentrations were detected on the air conditioning fins and the fan casing. This indicates that fungal growth was occurring on these surfaces. These results indicate that those surfaces require cleaning to remove mould growth.

RISK ASSESSMENT PROCESS

Information was collected from every room in the building using tick flick charts, indoor air quality monitoring (temperature, relative humidity, dew point temperatures, carbon dioxide concentrations and room air flow) and building structural moisture content (floors and walls).

These results were correlated with airborne and surface fungal results. An analysis of the indoor/outdoor ratio and fungal species shift was also conducted in conjunction with visual and destructive inspection data and photos to develop a risk matrix or grade of contamination of each room (AMG-2005-1; Cheong *et al*., 2004 & 2005). The mould grading and risk matrix developed will then allow facility managers or building owners to make prioritised decisions of the true risk of mould exposure and to which extent mould has proliferated and thus the mitigation and remediation measures required.

TYPICAL MOULD GRADING & SCOPE OF WORKS

Based on the information gathered from the initial visual inspection, background sampling and monitoring, further destructive and forensic sampling and moisture testing, each individual room was graded according to the level of mould contamination, and the level of mitigation and remediation works required as per the procedures set out in the Australian Mould Guideline (AMG-2005-1). From there, a scope of works was developed and tailor-made for each room in the building (Table 4). This sets out the requirements for mould contaminant removal and mould remediation, addressing the cause of mould proliferation, followed by reinstatement requirements.

Table 3 Typical Grading of Mould Damage in each Building

Ground floor

401	402	403	404	405	406	407	408	409	410
411	412	413	414	415	416	417	418	419	420

Top Floor

421	422	423	424	425	426	427	428	429	430
431	432	433	434	435	436	437	438	439	440

LEGEND:

Assessed as ok

Mitigated

To be further assessed or require further clean

Grade 4 contamination

Table 4 Typical Scope of Works

1. Beginning of Shift Administration:
   - Inform supervisor; time sheets; Job Hazard Analysis; Don on PPE; Pre-start meeting; Complete Take 5s.

2. Ensure appropriate level of PPE:
   - P3 filters with activated carbon, Respirators, Non-breathable Overalls, Taped up Gloves, Eye protection, Steel capped boots

3. Emptying out of rooms on both ground and top floor
   - Area is bunted off and signs erected; remove linen and curtains for washing; all furniture & beds removed for disposal

4. Hallway ceiling removal and remediation
   - Lay out drop sheets; no power tools to be used; all waste material carefully placed into bins

5. Cutting out top of built in cupboards and removal of bulkheads
   - Further inspection by trained mycologist to ascertain extent of penetration during cutting and removal process
   - Works to be supervised by site inspector; all cut out waste material to be carefully placed into bins; HEPA vacuum dust

6. Carpet removal in rooms
   - Rip out of carpets; any asbestos tiles mitigation by licensed and approved asbestos technician.

7. Mould and dust remediation of hallway ceiling and cut out built in cupboards
   - All surfaces to be HEPA vacuumed and damp wiped with mould cleaning solution as per Australian mould guideline AMG- 2005

8. Patch up, painting, gyprock, panels
   - Patch up , gyprock walls and panels: Ensure appropriate insulation is installed

9. Removal of air- conditioning units
   - Wall Mounted air conditioning units in Grade 4 contaminated rooms removed and disposed off safely

10. Final HEPA vacuum after all works are completed

11. Occupational Health and Safety & House keeping Issues
    - Electrical equipment to be tagged; electricity to block is isolated; If at any time any crew feel dizzy or nauseous, stop work, inform supervisor, then move out of working area; Regular spot breaks for hydration; Report any cuts or injuries to supervisor; Regular extended breaks and Job rotation; no crew to work alone for extended periods; Ensure work area is dust free

12. End of Shift Procedures
    - Empty vacuum cleaners; wipe respirators with alcohol wipes; Clean eye protection; Dispose used filters & overalls; inform supervisor and sign out.

After Remediation – Clearance Testing Results

Following the remediation works on the buildings, airborne mould clearance testing was conducted to compare the levels of mould exposure pre remediation and post remediation.

Table 5 Typical Comparisons of Average Indoor Airborne Concentration

	Before Remediation	After Remediation
Indoor Concentrations	2039 CFU/m^3	286 CFU/m^3

Typical Airborne Fungal Sampling

The Airborne Sampling results showed low to moderate concentrations of airborne mould. The Indoor Average of 177 CFU/m^3 was rated at Low-Moderate. This was lower than the Outdoor Air concentrations, which was also below the WHO guidelines (indoor concentrations to be less than half the outdoor air concentrations) (WHO, 1993; Cheong *et al,* 2004 & 2005). The comparison of species between the indoors and the outdoors shows a mixture of various fungal species at low concentrations and below outdoor levels.

Typical Airborne Fungal Spore Concentrations

The results show that all the locations had low (< 100 CFU/cm^2) airborne fungal (mould) spores. These results indicate that the cleaning to remove fungal growth was successful in bringing the levels back to normal background levels.

DISCUSSIONS & CONCLUSIONS

The steps undertaken in the remediation and management of exposure risk highlighted the need for a methodical and thorough approach when assessing the risk of mould exposure. This becomes more important in the prioritisation of tasks for mould mitigation and mould remediation processes. This case study details the steps required to conduct a complete risk assessment, supported by thorough and structured inspections, using forensic and destructive sampling for confirmation of hidden mould growth. The inspection, monitoring and sampling processes are integral to developing a scope of works. Constant renewal of priorities is required during discovery in order to develop the correct sequence of remediation steps. The key target areas, the remedial actions and the final scope of works would be significantly different if a predetermined investigation technique was strictly adhered to, especially where there is significant hidden mould growth in building cavities such as behind gyprock walls and ceilings.

The end results and analyses gathered from this thorough and scientifically based methodology, allow facility managers or building owners to make specific and informed decisions. This also aids in biohazard communication to advise clients or occupants of the true risk of mould exposure and to which extent mould has proliferated and the scope of disruption that will be incurred due to mitigation and remediation measures.

The key to reducing the risk of mould exposure is to identify long term mould problems by persisting with destructive and/or forensic sampling until the ultimate source of the moisture or mould growth is discovered. This is the only way to ensure that the underlying problem will be permanently fixed (AMG-2005-1). Simply removing mould contamination, cleaning the area and reinstating the property will not necessarily mitigate the risk of mould exposure.

Conducting risk assessments for mould exposure in indoor environments can be difficult due to the lack of any international or national guidelines or standards. In many instances, mould investigations and laboratory reports are highly subjective and often place the burden of interpretation on to the end client. Stricter regulations and set procedures such as those highlighted in this case study should be considered when establishing industry standards for mould investigations.

Environmental Consultants, Occupational Hygienists and technicians involved in the assessment and inspection of mould require specific training and set systems and procedures to communicate scientific results that will empower the clients to make informed and rational decisions. Proper accredited training in mould investigations and remediation with certification procedures, guidelines and industry standards will enhance the general understanding of the risk assessment process for mould exposure. Government adoption of Mould Guidelines and Standards with industry based audits will then reinforce the concepts of a proper risk assessment for mould exposure. Should all of these be in place, the client or building occupant will then be able to obtain solution based outcomes to their mould exposure issues.

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