ENVIRONMENTAL ASSESSMENT OF PATHOGENIC FUNGI WITH SPECIFIC REFERENCE TO A SYDNEY UNIT INFESTED WITH TERMITES - POTENTIAL FUNGAL IMPACTS

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ENVIRONMENTAL ASSESSMENT OF PATHOGENIC FUNGI (LITERATURE REVIEW) WITH SPECIFIC REFERENCE TO A DEPARTMENT OF HOUSING SYDNEY UNIT INFESTED WITH TERMITES – POTENTIAL FUNGAL IMPACTS

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AIM

To investigate aspects of Sick Building Syndrome (**SBS**) and the symptomology of 2 Department of Housing (DOH) residents in a villa in South Windsor in relation to a severe termite infestation.

METHODOLOGY

Research

Interviews with the subject have provided relevant information regarding the succession of events at the villa, culminating in the symptomology expressed by the subject and her daughter. Telephone and personal interviews with Mr Chris Derry BSc(EH)(UNISA), BSc(Med)Hons(UCT), MSc(Med)(UCT), DTE(UNISA), Lecturer in Environmental Management and Agriculture; Mr Sandy Booth MSc, Visiting Fellow and Director of the Centre for Integrated Catchment, and Ms Sue Reed, MSc(EngSc), Senior Lecturer in Occupational Health and Safety Programs in Engineering Noise Control, Hazardous Substance Handling, Epidemiology and Occupational Hygiene (all University of Western Sydney, Hawkesbury) focused this investigation on the cumulative impacts of fungi, termites and damp in **SBS**.

Literature research provided the means by which environmental factors, eg termites, mold (dry rot fungi) and other environmental fungi species could potentially account for pathogenic symptoms in the main foci of this investigation, the subject and her daughter.

EXPLANATORY NOTES

Names of Subjects

The main subject is a female in her thirties. The subject's daughter is about eleven years of age.

Referencing

Referencing is in the Harvard style.

I have used blue font to distinguish paraphrased and extracted material from my surrounding work. The blue font is used to define specifically paraphrased material.

Where I use the blue font convention and I state that an author is referencing another author, eg Muir 1996: 351, referencing Bryant 1982:692, that means I have paraphrased the first author's paraphrase of another's work.

Where references are third party and are excessive in numbers, they will be displayed in a single footnote in the Harvard Style. The full reference details can then be found at the end of the document.

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This means, necessarily, the use of *American/English*, not Australian/English.

Footnotes

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start on the next page. Also, footnotes can continue from one page onto the base of the following page (this is a normal technical problem with Microsoft Word).

INTRODUCTION

This investigation examines environmental fungi, and centers on a possible association between fungi and termites in a **SBS** example. The main points of concern in this problem are the disturbing physical symptoms expressed by the two occupants of a villa, the presence of a notable problem with damp and mold, and a significant termite infestation.

The main location of interest in this assessment is a Villa in Cox Street, South Windsor NSW (2756) in North-West Sydney, a DOH residence under the authority of the Richmond Office of the DOH (PO Box 155 Richmond NSW 2753, ph. 0245704999). The occupants of the villa – those displaying an array of symptoms – are the main foci of potential pathogenic fungal influence.

DISCUSSION

Fungi and Termite Basics and Initial Health Concerns

Fungi can cause disease. Fungal infection can initiate an allergic response. Some fungi contain metabolic products that are toxic to human hosts. These compounds are called mycotoxins (Tottora, Funke & Case 1995:402). They are secondary metabolites and ultimately poison through the inadvertent ingestion of, or contact with, a substrate containing the toxin-producing fungus (Kale & Bennett 1992: 311-312). Fungal infections are called mycoses (Tortora, Funke & Case 1995: 301).

Neuroactive mycotoxins (defensive toxins), eg tremorgans, find good application in multicellular organisms with a nervous system. These toxins interact with a diverse number of neurotransmitters and receptors. Many of these neurotransmitters are present in the insect nervous system, which shares many similarities with vertebrate nervous systems. There appears to be a parallel between the acute toxic effects of mycotoxins in insects and vertebrates. In fact, the equivalence of detoxifying enzymes in vertebrates and insects, suggests that fungal secondary metabolites may

amplify the toxicity of mycotoxins in vertebrates and other organisms. In this regard, vertebrates may be poisoned by mycotoxin defenses designed to deter insects (Dowd 1992:142-144).

Further to the above: The adaptability of many fungi in being able to flourish at human body temperatures creates the potential for pathogenicity. This potential is increased when the host is compromised by stress (Ingold & Hudson 1993: 195).

Termite worker insects collect and eat plant debris and wood. Their fecal pellets are made into combs within chambers. A fungal mycelium then colonizes and permeates each comb. The asexual or conidial stage of the fungus and the mycelium form the most significant part of the termite diet (Ingold & Hudson 1993: 195).

This information points up some basic concerns in this study. It is highly likely that the fungal mycelium associated with the termite infestation is producing mycotoxins and/or spores that are impacting on the health of the subject and her daughter.

A Potential Cascade of SBS Problems

Reports of negative health effects centering on discomfort have increased in regard to the nonindustrial workplace. *Sick building syndrome* (**SBS**) is the term now used to describe common nonspecific symptoms linked with occupations in office buildings (Wan & Li 1999a: 58). **SBS** can also be applied to homes.

The first point I wish to raise in explaining the infestation in the villa is an interior problem with mold affecting leather goods. On a regular basis water has been noted running from an uphill residence, over concrete toward the villa in question, which appears to be situated over clay. The moisture problem indicated by the presence of the mold (and water stains on timber underneath the villa) explains the attractiveness of the Villa's timber structure, in reverse, to mold in the first instance[1]. This is because, for example and specifically, the Basidiomycete fungus *Serpula* (*Merulius*) *lacrymans* can initiate growth in high moisture content timber[2] and, using the nutrients and energy thus gained, can send out rhizomorphs which can then colonize dry timber many meters away from the site of initiation. The rhizomorphs can not only transport water, but water can be produced wherever the fungus is active. This mode of colonization is also available to other hyphal fungi (Eggins & Allsopp 1975: 305). Fungi produce a degradation of wood and termites are attracted to, and indeed thrive on, the cellulose and pentosans produced in the initial stages of attack (La Fage & Nutting 1978: 180). As well, termites need protein in their diet and this can be supplied by wood decay fungi (Hadlington 1996: 17).

Should the fungi, in particular, be generating more moisture, then an explanation for the excessive wetness of the soil under the main bedroom may be found, unless most of this moisture is derived through seepage from properties uphill. I investigated the sub-floor region of the villa on Friday 11th February, 2000. The details may be found ahead in the next section.

Wood-rot fungi, as well as the termite fungal mycelium, may also be poisoning the occupants of this villa via the agency of fungal mycotoxin defenses.

Inspection of Premises

[1] The wetness of the soil under the villa speaks of a very humid environment. Humidity aids fungal growth. Water can condense on flooring undersurfaces and structural timbers, thus eliciting the conditions necessary for the germination of fungal spores and consequent development of decay fungi (Hadlington 1996: 17).

[2] Dry wood cannot be colonized by fungi unless the moisture content is greater than 26-32% on a dry mass basis. *Serpula lacrimans* can establish itself on a small area of damp wood (Ingold & Hudson 1993: 145).

On Friday, February 11th 2000 this author inspected the interior and sub floor areas of the villa. Two termite mounds (one quite large: 0.6m diameter at the base, 0.8m high and 0.35m diameter at the apex; and another smaller one: 0.45m, 0.6m and 0.3m) were observed. These occupied two south-east sub floor corners of the main bedroom. The mounds extended from the soil surface up to and including (covering) the horizontal supports. Not only did these supports show water stains extending in from the east wall, but the soil in this corner was extremely wet[3]. Approximately 400 square cm of this mound was covered with a white substance, which may have been fungi. It should *not* have been arsenic trioxide because the pest technician should have inserted this toxic heavy metal *into* the termite mound via bored holes. This is in accordance with the Code of Practice for the Safe Use of Pesticides (National Health and Medical Research Council 1990:Cover,5).

Figure 1 ***Southeast corner wall of main bedroom (where the daughter slept).***

The Unit and the Subjects' Symptomology

[3] The ready availability of water is likely the single most significant environmental factor affecting the growth of fungi (Cooke & Whipps 1993:85).

The Villa has been infested with termites for at least 3 years. As of the writing of this document, the Department of Housing had failed to address this problem since they were first notified in 1997. Only in December of 1999 did a pest technician finally make an appointment to inspect the premises in that month. This appointment did not materialize until January 2000, whereupon the subject was advised by the technician that the unit was suffering significant structural damage. A Hawkesbury Council building inspector had also noted that the villa should be **condemned**.

The subject has spoken of ongoing stress induced by this failure to address her concerns. As well, she noted that the Department seemed to be more concerned with extracting rent while refusing to inspect evidence of the internal termite infestation and damage, including significant damage to her personal property (an expensive bedside cabinet was attacked by termites breaching the main bedroom wall within a 48 hour period). Further to these problems are her concerns for her personal safety and that of her daughter. This issue particularly relates to the shuddering of the villa in windy conditions.

According to the subject, the Department has failed to show any real concern. They have not offered to transfer the subject and her daughter to a habitable apartment, even after frequent requests. This account particularly relates to the information offered in the previous section on stress compromising the body's ability to resist pathological impacts.

The subject has experienced almost daily headaches for months. The daughter has suffered a headache approximately every 3-4 days, has had continuous skin rashes for months, and is a chronic asthmatic.

In relation to this, profiles on symptomology expressed by 1,237 office workers in Taipei (subtropical climate; similar to Sydney, eg air temps: 24.1 °C – 32.9 °C; rel. humidity: 42% -- 77% [Wan & Li 1999b: 174]) showed that skin symptoms were most notably related to dampness, with headache being the next most common symptom (Wan & Li 1999a: 60). Also, β-1,3-glucan – a fungal cell wall glucose polymer – can provoke inflammation and impact on the human immune system[4]. Researchers have determined that microbial contamination, in the form of bacterial endotoxins[5] and β-1,3-glucan[6] are linked with **SBS** in living quarters and office buildings (Wan & Li 1999b: 172). Studies show that β-1,3-glucan levels in moldy homes can be anywhere between 50 to 100 times greater than that found in office buildings and daycare centers[7]. Bioaerosol levels have been found to be linked with the level of dampness in indoor environments (Wan & Li 1999b: 173).

In particular, daycare centers showed the highest levels of median contents of indoor bacteria and fungi – 7,615 CFU/m^3 and 854 CFU/m^3, respectively. Homes registered 2,907 and 695 CFU/m^3. Office buildings registered the lowest values. *Aspergillus, Alternaria, Cladosporium, Penicillium and yeast* registered at levels of 0-177, 0-18, 12-318, 24-1,437 and 0-1,714 CFU/ m^3, respectively. Strong associations were established between mold and shortness of breath. As well, elevated fungi counts were noted in environments with elevated temperatures, humidity and water damage. High β-1,3-glucan levels were strongly associated with mold and water damage. This is because dampness is a key growth factor for microorganisms and there exists a strong association between higher humidity and water damage and higher bioaerosol levels (Wan & Li 1999b: 175,177).

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[4] Wan & Li 1999b: 172, referencing Czop & Kay 1991: 1511-1520; DiLuzio 1985: 387-400; Johnson, Glovsky & Schrier 1984: 515-516; Patchen & Mac Vittie 1983: 303-313; Sherwood, Williams, McNamee, *et al.* 1987: 261-267; Williams, Pretus, McNamee, *et al.* 1991: 139-156; Williams, Pretus, McNamee, *et al.* 1992: 247-257.

[5] Wan & Li 1999b: 172, referencing Rylander, Persson, Goto, *et al.* 1992: 263-267.

[6] Wan & Li 1999b: 172, referencing Rylander & Snella 1983: 332-344.

[7] Wan & Li 1999b: 172, referencing Rylander, Persson, Goto, *et al.* 1992: 263-267; Rylander, Hsieh & Courthouse 1994: 159-162.).

The subject has experienced an unusual fatigue for some months. In early December of 1999 the subject and daughter started experiencing dull and diffuse pain in the arms. Also, the lymph nodes at the back and base of the respective individuals' skulls started enlarging. Pain accompanied this enlargement, along with eye irritation. The subject is currently seeking a CT scan to hopefully provide some form of clear diagnosis.

In mid December of 1999 the subject awoke in the early morning with heavy heart palpitations, numb arms and a numb face (the palpitations and arm numbness had disturbed her sleep until she awoke completely). Some nausea and significant vertigo were also experienced. The feelings of numbness would last for at least 20 minutes and were relieved a little through massage and the maintenance of a vertical position. The arm numbness and a less notable numbness in the rest of the body continued on for about 3 weeks after this acute episode. As well, the subject has continued to experience episodes where her legs lose the ability to support her. This symptom creates a slow-motion collapse and a staggering attempt to recover her balance.
In late December 2000, both the subject and her daughter holidayed in Cooma. The lymph nodes in both individuals remained the same size for the 12 days they were away from the South Windsor villa.

On the 9th February 2000 (6 weeks from the first significant symptoms of lymph node impact) the subject's hands still experienced some numbness. This was especially apparent when holding the telephone. Both arms still experienced weakness at this time. The subject was still having episodes of losing the support of her legs.

Although the subject smokes, the acute symptoms noted in the early hours were likely not significantly related to vasoconstriction which can potentially occur when the body becomes inactive after the use of cigarettes (Chris Derry 2000, pers.comm. Feb 11). This is because the subject's smoking is a *constant* theme in the circumstances of living in the unit. The *variable*, and therefore the major suspect, is the combination of the damp, mold and termite activity, the latter being audible at night. The development of the symptomatology was concurrent with the worsening state of the infestation, while other usual or predictable lifestyle factors continued on without significant variation.

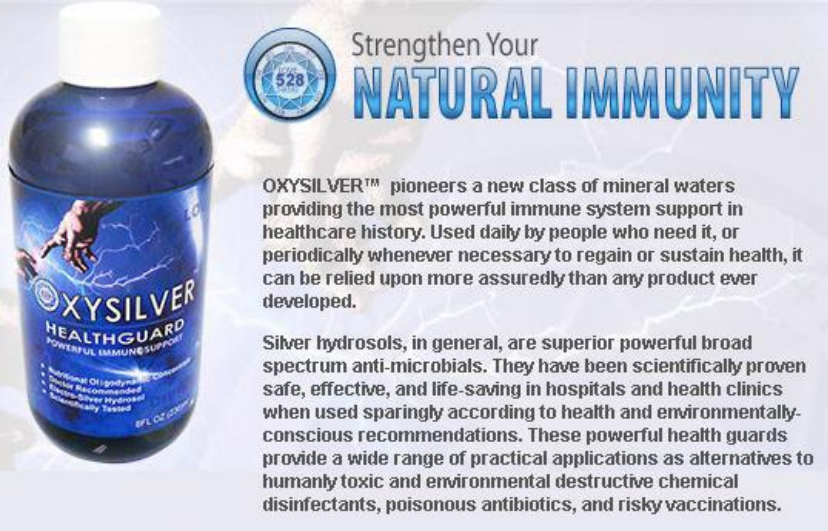
Should it be the case that these symptoms are not representative of gross neurological events promoted by fungal toxins, then both subjects may be, at the very least, hypersensitive to wood-rot fungi (Chris Derry 2000, pers. comm., February 11) or just normally reactive to extremely high levels of **bioaerosols**. This is, in part, supported by Koskinen *et al.* (1999: 143), who showed that schoolchildren exposed to mold experienced an increased risk of nausea (one of the subject's symptoms in the acute episode in December 1999). Also, the same authors note that asthma relates to damp or moldy housing (Koskinen *et al.* 1999: 143-144, referencing [8] in the footnotes), which tends toward the generation of non-respiratory symptoms such as aches and pains, nerves, headache and eye irritation (Koskinen *et al.* 1999:143-144, referencing [9]).

As noted above, the subject and daughter experience frequent headaches (and the subject suffered arm pain, especially during the December episode and for a few weeks afterward) and the daughter has skin rashes and is a chronic asthmatic.

The longterm development of organic disease in this study is an as yet unknown dynamic factored upon the duel concerns of the subject's smoking habit and indoor airborne particulate matter originating from fungal spores within the structure of the villa (the subject smokes outdoors, therefore cigarette smoke generally does not influence airborne particulates inside the home for any considerable period).

[8] Waegemaekers *et al.* 1989: 192-198; Brunekreef *et al.* 1989: 1363-1367; Dales *et al.* 1991: 196-203; Dekker *et al.*1991: 922-926; Brunekreef 1992:79-89; Sprengler *et al.* 1994: 72-82; Timonen *et al.* 1995: 1155-1160.

[9] Martin *et al.*, 1987: 1125-1127, Platt *et al.* 1989: 1673-1678, Waegemaekers *et al.* 1989: 192-198, Dales *et al.* 1991: 196-203, & Braback *et al.* 1995: 487-493.



The concern here focuses on, not only the acute symptoms experienced by both tenants (as well as an ongoing problem with asthma in the daughter and the recent reemergence – February 2000 – of a raised profile in the neck lymph nodes in the subject, with pain), but also in toxicological studies of indoor airborne particulate matter showing that it can inhibit intercellular communication (this might explain the subject's acute problem with numbness). As well, these studies have determined that, in addition to mutagenic activity, samples of airborne particulate matter also generate tumors (Micallef, Colls & Caldwell 1999: 5-6). These authors note that Heussen *et al.* (1992: 6-12) have shown in studies on rats that airborne particulate matter has the capacity to obstruct thyroid hormone metabolism and, likely, vitamin A metabolism as well. The authors also observe that epidemiological studies have generally demonstrated a correlation of morbidity and mortality with fine particulate matter.

From this perspective, fungal spores arising from mold in the villa take on ominous proportions. An added concern arises from the potential of externally originating spores becoming active within the humid and damp environment of the structural timbers of the villa. This potential is examined next.

Fungi & Termites – A Broader View

When we note that subterranean termites associate intimately with organic materials and can range up to 50m or more from the main colony (Hadlington 1996: 17), it is not unreasonable to assume that some fungal spores must attach to termites (or

even be carried in the gut) and be transported to any satellite location where termites are attacking wood (Sue Reed & Sandy Booth 2000, pers. comms. 9th February). This study suggests that termite activity in a house or unit may establish pathogenic potentials that are yet to be discovered.

Allergic alveolitis (chronic asthma) is attributed to the presence of the spores of dry rot fungi and many other common environmental fungi. The suspected wood rot fungi are: *Serpula lacrimans* and *Leucogyrophana pinastri* (Muir 1996:351, referencing[10]).

The other fungi implicated by the above authors are *Trichoderma viride, Paecilomyces varioti, Aspergillus fumigatus, Geotrichum candidum, Aspergillus ochraceus, Alternaria alternata, Fusarium solani, Mucor* sp., *Mortier* sp. and *Phoma glomerata* (Muir 1996: 351). *Penicillium* has been noted as a causative agent of allergy (Muir 1996: 351, referencing [11]). The microfungi *Aspergillus* species are well known as allergens, particularly in relation to pulmonary allergic reactions (Chris Derry 2000, pers. comm. February 11).

The *Kirramyces spp.* (*Coeloanamorphoses, Fungi Anamorphici)* fungi, specifically *Kirramyces lilianiae*, have been found on the tree species *Corymbia eximia*, known previously as *Eucalyptus eximia* (Walker 1996: 289). Simpson (1996:106, referencing [12]) says that the main causes of breaching of compartmentalization barrier zones in species of *Corymbia* are mechanical stresses or insect damage. This points up the possibility of a fungal infestation following termite attack in trees and leads into a supposition that the transfer of environmental fungi to housing, particularly into moist, hospitable environments enhanced through the actions of wood rot fungi and termites, may be a contributor to **SBS**.

Given that fungal growth is probably more dependent on access to water than any other environmental factor (Cooke & Whipps 1993: 85), humidity in or under human

[10] Bryant 1982:692; Bryant & Rogers 1991: 89-94; Stone, Macauley, Johnson, Holmes, Thornton & Tai 1989: 727-729.
[11] Adisesham, Simpson & Gandevia 1971: 385-391.
[12] White & Kile 1993: 431-440; Wilkes 1985a: 17-22.

habitations provide environments and opportunities for environmental fungi to become acutely pathogenic.

Specific instances, such as indoor mold and an acute infestation of termites, must therefore raise concerns over the direct influence of fungi on humans within a relatively confined space.

CONCLUSION

The subject and her daughter demonstrate a classic range of nonspecific symptoms associated with **SBS**: headaches, skin irritation, fatigue, bronchial distress and eye irritation. The villa in South Windsor has been inspected by this author and water damage and considerable dampness affects the sub floor structures and soil. As well, an extreme termite infestation has also taken hold on the home. Problems with bioaerosol contamination in the form of bacteria and fungi are considered to be affecting the occupants significantly, so much so that the biological environment of the villa is compromising immune function in both individuals.

It is probable that mycotoxins produced by the fungal mycelium in the termite combs and the wood rot fungi, which are designed to repel insect invaders, are impacting on the health of the subject and her daughter.

There is some likelihood, also, that the damp structural environment of the villa may have favored other environmental fungal spores. The possibility exists that eucalyptus species may have contributed fungal pathogens to the home. Whether these spores (eg *cryptococcus*) explain the severe symptoms expressed by, especially, the subject is not known. Nevertheless, it is certain that some fungal pathogens have impacted on a disturbing scale in this particular case.

Concerns are expressed by this author that the increasing summer humidity in Sydney, along with factors such as urban sprawl, poor drainage and environmental laws proscribing the removal of trees in new housing developments, may be favoring a new disease regime for urban areas.

Addendum: The 2 subjects moved out of the unit due to aggravated dissatisfaction with the DOH, and their severe symptoms.

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