Failure to correctly identify water damaged buildings and contamination may result in unnecessary costs and Building Related Illness (BRI)

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1. Abstract

The investigation of water damaged buildings is internationally undertaken on a daily basis to assess cause, effect, extent of damage and sometimes health and safety risks . The accuracy of investigation may depend on tools, equipment, training and specialist support such as laboratories

This paper highlights some of the sampling and investigation errors of typical industry protocols used and why conclusions are sometimes flawed and may lead to continuing health impact or needless restoration and decontamination cost. Sick Building Syndrome (SBS) [1-68] and Building Related Illness (BRI)[2] [3,68] are recognised as major issues in building occupant health. A literature review of referenced papers and documents throughout this paper will show how contamination components and building defect, can affect health and wellbeing either individually or synergistically. While these references make clear the potential risks and hazards of individual components, there is also a general recognition that the complex symbiotic effects of chemicals and biological activity make definitive and objective investigation very difficult.[7-10-11-12] The investigation of most SBS or BRI will revolve around the limitations of budget and competence of the investigator coupled to the required outcome. While definitive objective investigation may be possible, it is often at a high cost, not least when legally proven evidence is required. There is therefore a requirement for all stakeholders to recognise the benefits of a decision making log, which may, or indeed may not exclude, rather than confirm contaminates and recognise risk rather than confirm hazards present. This paper sets out to provide understandable explanation as to why Indoor Environmental Health Professionals (IEPs) should be a first choice and that cost is a very poor guide of value against the limited skills and equipment limitations of the semi-professional and DIY survey. The paper should alert all stakeholders to the difficulties in assessment of cause and effect.

2. Summary

The level and complexity of water damaged building (WDB) investigation will revolve around risk and hazard assessment, cost and the required outcome or information. Typically, where the cause and extent of water damage is known and professionally restored and a small amount of visible mould is removed; there is little need for a professional survey. Where mold growth is less than 10 square feet or 1m² UK and USA

government bodies recommend do it yourself (DIY) [4- 5- 67] Where visible mould is present there is usually no requirement to test or identify it, as in all cases, it must be removed. [9] An exception to this is where there is current or historic water damage and occupant health may be associated with exposure. In this case an Indoor Environmental Health Professional (IEP) may be required to undertake in depth analysis and reporting. This paper provides an introduction to the differences and importance of recognising the needs of the normal client with a little visible mould and the atopic victim with debilitating health effects such as CIRS [6] and general water damage related illness.

The importance of identifying the correct testing and investigation technology is coupled with their obvious failures and this paper attempts to highlight some of these issues. While the paper focuses on usual shortfalls in building and health related surveys, you will recognise this is not a training document other than in avoiding possibly expensive mistakes and poor decision making based on flawed evidence. These issues were identified by US Government Accountability Office (GAO, 2008) report [7] and the World Health Organization report (WHO, 2009)[10] "There are many compounds, both toxigens and inflammagens, present in the indoor air of a WDB that have been identified within the complex mixture found in the air and in the settled dust of the interior environments of WDB. Further, there is clear data showing that each of these compounds can initiate an inflammatory host response such that no single compound can be identified as the sole cause of the inflammatory responses seen in affected patients.[11] Since many sources of inflammatory stimulus exist, some of which are synergistic, and no single causative agent within the WDB can be deemed to be solely responsible for the symptoms exhibited. The sole causative agent becomes the interior environment of the WDB itself. [7 12] The "Consensus document" [12] written by a panel of Indoor Environmental Professionals with Surviving Mold reflects on many of the issues surrounding cause effect and remediation. This document adds to the consensus document by drilling down to some of the some of the core issues encountered while developing a meaningful report. [8] This paper may be of significant use to those suffering Biotoxin illness, CIRS[13] who might identify avoidable mistakes in assessment of their building risk and hazards.

This is not a medical paper but is aimed at assisting those that may not realise the symptoms they display are possibly related to known genetic differences such as the HLA gene [14] and specific types of contamination [8]
Those that do suffer typical symptoms may wish to check their symptoms against the online VCS test [15] and of course seek specialist medical help.
This document explains shortfalls in typically used investigation and sampling protocols but even the worst have some benefits and it is for the professional IEP to identify where and when different techniques can be used.

3. Survey Requirements

A survey should be designed to fit the client's requirements which are of course varied.
The client's requirements may revolve around;

- Extent and cause of damage
- Biological contaminates and risks
- Occupant health and possible relationship to WDB
- Health hazards generally and exposure routes
- Resolution and recommendations

- Budget

Budget is unfortunately the major risk factor in terms of report usefulness.

4. What is water damaged building? (WDB)

The indoor environment and ecosystem is seen as a microenvironment of interrelated physical and biological factors, all of which can result in a reservoir or source of pollutants. Bacteria and mould spores are ubiquitous and omnipresent and coupled with general dust and organic matter; it takes only a little moisture to activate bio amplification often within 72 hours [68]. The living or biological indoor environment includes proteins, enzymes, endotoxins, mycotoxins, glucans and Volatile Organic Compounds [12] (see Table 4) Normal building ecology contains both living and dead (viable and non-viable) microorganisms[10] When uncontrolled and excess moisture is introduced into the built environment the normal fungal ecology shifts to the more water tolerant species of mould such as Stachybotrys, Chaetomium, and Ulocladium [68]. This water is called free water and is available to microorganisms for growth and is described as water activity and is noted as a_W . Water activity can be compared to equilibrium relative humidity (ERH) of a material [7] Free water which has been loosely absorbed should not be confused with "Bound Water" which is chemically and molecularly bonded to internal surfaces and is very difficult to remove but equally may not affect a_W [16, 68] Many fungi have a minimum (a_w) requirement such as Penicillium, Cladosporium ,Aspergillus at 0.80 to 0.90 aw which corresponds to 80 -90% ERH[68.] ERH and a_w should not be confused with relative humidity which is air measurement whereas ERH is surface condition. Thus the definition of a water damaged building might be expressed as elevated ERH above 0.80 a_W and or >80%ERH.[17-18] Decay follows, as does the proliferation of gram negative bacteria, actinomycetes, spores etc [19]

5. Investigation of Building Related illness

There is little doubt that a water damaged building can cause health effects to occupants especially the atopic. The type and extent of testing and sampling may be influenced by both cost and or doctors requirements. All fungal spores and fragments can be allergenic whether viable and inviable [68] Technically the atopic occupant is exposed to "pathogen associated molecular patterns (PAMPS) and this can lead to the production of danger associated molecular patterns (DAMPS) [12] Unfortunately the atopic CIRS patient has an egg shell vulnerability and the first step in developing a testing hypothesis and scope of testing may require a blood test for inflammagens.[20]

6. Survey Types

The following section explains the different types of surveys available and their individual benefits and or limitations.

6.1. Do it yourself (DIY)

This is possibly the most important and regularly undertaken of all surveys but one which can lead to a poor decision making process and failure to resolve building defects and health issues. DIY surveys often use swabs and mould tests purchased on line. These tests are of limited value as can be seen discussed throughout this document. The reliance on safe or high in terms of risk is extremely misleading and has no real value. There are no meaningful standards on maximum exposure levels for mould and or the multitude of possible synergistic effects. Visual assessments are very useful but sometimes water damage and their effects can be hidden in cavities and behind wall paper and false assessments result. DIY is however useful to identify

unusual and often new effects such as, swelling and cracks and of course tell-tale signs like odor and visible discoloration or actual mold growth. Where visible or olfactory markers are present they should be investigated and resolved following typical protocols such as NYCG [4] DIY sometimes undertake ERMI [47] and other biological sampling by swabs and dust collection and don't understand the results and ask an IEHP for Interpretation. ERMI has not been validated for this type of use. [48] Analysis of the lab report without knowing the sampling protocols and background are almost worthless and likely to be misinterpreted.[43] The EPA state ERMI score cannot be used commercially and is a research tool only and should not be used for clearance or risk assessment [21, 48] The laboratory analysis used by ERMI[49] by QPCR does provide exceptional data and this has been used by HERTSMI 2 [23] as a risk and hazard assessment tool [22-23]

6.2. Building Surveyor

When buying a house a very straight forward structural survey is usually undertaken by a registered building surveyor [24.] The surveyors role is usually to identify possible defects or latent damage which may detract from the asking price or value of the property, This type of survey usually include damp but almost always exclude mould and contamination issues and rarely are intrusive and almost never use any equipment other than a simple and basic moisture meter. They are generally designed to assess cost or value, legal compliance to land and building regulations and building code. While of critical importance to mortgage companies they are not environmental surveys and have little or no use where environmental or health concerns exist such as BRI[2-3-68] exist.

6.3. The Water Damaged Building Survey (WDB)

Sick Building Syndrome [65] (SBS) and Building Related illness [66] (BRI) and Chronic Inflammatory Response Syndrome (CIRS) all have at least one common component, water. Uncontrolled water in the form of penetration, leaks, floods, elevated humidity ratio and or even dew point condensation can result in bio amplification within 72 hours [25,68]. The uncontrolled moisture in the form of specific humidity, or dew point condensation and contact may activate the omnipresent mold spore, cause decay and may release Volatile Organic Compounds (VOCs) Bio amplification will also depend to some degree on temperature and cellulose or organic content of affected materials. Biological amplification and decay can take many forms as can be seen in Table 4 [12] The spread of contamination can be through artificial ventilation or convection currents and this can be affect different floors and rooms within minutes [68-70] Bio amplification will also depend to some degree on temperature and cellulose/organic content of affected materials. Biological amplification and decay can take many forms as can be seen in Table 4 [12]. Many contaminates seen in Table 4 will remain in dust and particulates years after the water has evaporated and the substrates and surfaces are dry. It is therefore of paramount importance that WDB surveys accommodating both current and historic events.

Method

The objective is to measure moisture or water in its various forms but specifically liquid and vapour phase. Moisture meters, thermal hygrometers are used in combination with Psychrometric charts to assess moisture content of substrates and air.

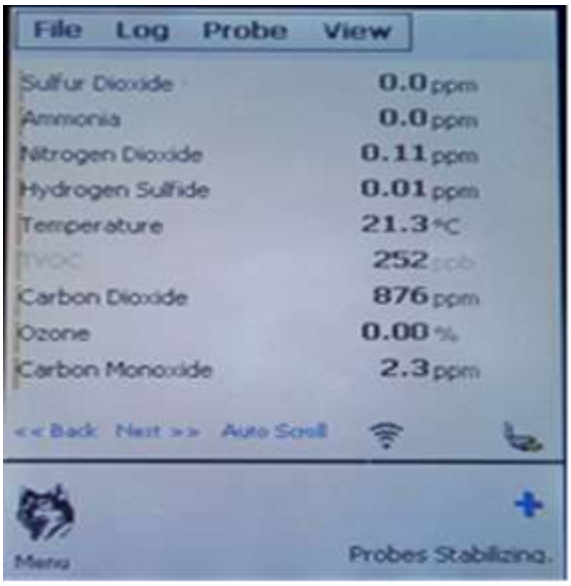
6.4. The Environmental Survey

This survey provides a range of important but limited assessments on the built environment but almost nothing in terms of biological activity which can be used in health risk or hazard assessment. The information may not provide anything other than a reflection of external air quality such as traffic fumes etc. The carbon monoxide [26] and carbon dioxide levels [27] especially, can be important as these can help assess ventilation rates and occupant safety. [28-29] Although these are useful assessments they cannot be used as standalone information in building related illness. This surveyor will measure, temperature and relative humidity which have very limited value. They may also assess the presence of visible mould and comment on lifestyle issues.

The environmental surveyor may sometimes also measure:

- Total Volatile Organic Compounds
- Carbon dioxide
- Carbon monoxide
- Sulphur dioxide
- Nitrogen dioxide

While some gases are indicators of traffic pollution, important gases like formaldehyde which can off gas from wet building materials cannot be identified by the average PID [30]



1 The environmental survey undertaken with PID

Method

The environmental survey is undertaken with a range of electronic sensors coupled to visual assessments

6.5. Using airborne particulate contamination as a guide to investigation

Table1 below shows the levels of airborne contamination throughout the property. It can be seen that the lounge, kitchen and study had the highest levels of contamination. The differing floor coverings and drapes and air pathways were contributors to these results and therefore may be meaningless as standalone

measurement. Particle counting can be very useful prior to air sampling to assess airborne debris loading which can mask or occlude laboratory visual assessments See Table 3. Particle counting can assist in the identification of problem areas but the shortfalls must be recognised.

Galileo first discovered that in a vacuum, if you were to drop two objects from the same height, they'd hit the ground at exactly the same time, regardless of their respective size and weight.[31] Due to air resistance different sizes, shapes, aerodynamics and weight, particles will fall or settle at differing rates according to Stokes law [32-33] This means that different mould and fragments of bio amplification particulate will settle at different rates and indeed re aerosolise at differing rates depending on their size. Aerodynamics, air movement (air pathways) and environmental factors such as barometric pressure and humidity and physical disruption also contribute to airborne loading. The significance of particulate identification can be indicators of serious health hazards from biological fragments.[37.] While particle counters cannot identify anything other than size and quantity this information may assist in the risk assessment of the smaller and often higher risk particulates[37] The inlet velocity and volume cubic feet per minute (CFM) of any particle counter will also have an influence on what it captures and identifies. The following reference video shows how poor particle capture is, even when using a 1000 cfm Negative Pressure Unit and how only particles close to the mouth of any vacuum system are entrained [38]

The Health and Safety Executive (HSE) undertook a detailed investigation of Strata air and the practicalities of using Negative Pressure Unit (NPU) Filtration devices in their publication RR988. [39.] This document confirms the stratification of particulates depending on buoyancy etc. The implications of the paper RR988 are that particle counters should be used at differing heights and over several hours, possibly with air disturbance. Unfortunately the study also indicates that NPUs are not effective in removing airborne contaminates and confirms the shortfalls of all air sampling and of course the historic protocols of NPUs when used for decontamination or "Air Scrubbing". Most air scrubbers are HEPA filter rated. This means they capture 99.97% of .3 particles. These machines require frequent performance testing as movement and transportation can affect internal seals.[72] Unfortunately, domestic vacuum cleaners are rarely tested and they can be reservoirs of contamination and cause aerosolisation of contaminates through their exhaust port. In one reported SBS investigation the vacuum cleaner was found to be the main contamination source [68]

Method

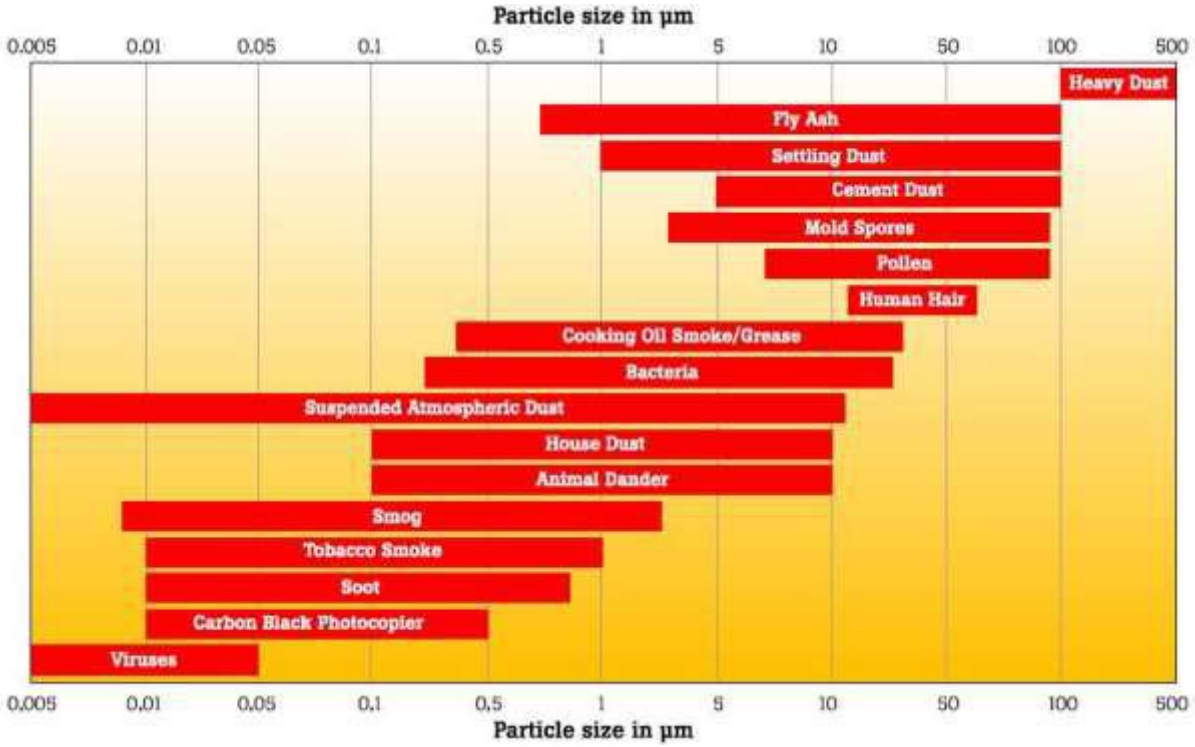
A hand held particle counter is used to capture and record differing levels of airborne particulate size and quantity. The sizes usually range from .3 to 10 micron

Table 1

Particulate size µ	Melody bed	Bedroom	Study	PC bedroom	Lounge	Kitchen
.3	1391	2119	4936	4746	9332	9223
.5	454	685	1680	1916	2623	3454
1.0	51	135	265	311	479	460
2.5	6	22	90	54	105	101
5.0	1	13	48	21	52	44
10	0	7	26	2	20	19

2 Showing a typical capture of recorded measurement on a 6 channel particle counter.

Table 2



Typical particle sizes of airborne contamination

Table 3

Debris Rating	Description	Interpretation
None	No particles detected.	No particulates on slide. The absence of particulates could indicate improper sampling as most air samples typically capture some particles.
<1	No particulates on slide. The absence of particulates could indicate improper sampling as most air samples typically capture some particles.	Reported values are not affected by debris.
1+		
2+	Decent visibility. Particles beginning to crowd.	Non-microbial particulates can mask the presence of fungal spores. As a result, actual values could be higher than the numbers reported. Higher debris ratings increase the probability of this bias.
3+		
4+	Poor visibility. Particles beginning to overlap.	Excessive debris detected in the sample. Counts reported may vary drastically and actual values could be higher than the numbers reported. The sample should be collected at a shorter time interval, or other measures taken to reduce the collection of non-microbial debris. In addition, a >4+ rating will only allow for a count from the
>4+	Poor visibility. Particles overlapping.	

	perimeter of the slide.

The typical Total Spore Count lab report caveat showing why airborne debris occluded visual detection thereby making the air sample of limited use or benefit

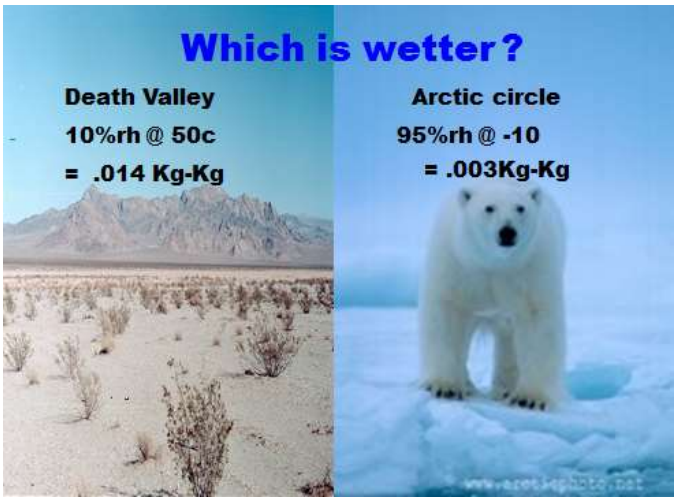
6.6. Electro Magnetic Radiation

Electromagnetic fields can be measured to assess levels and possible “Hot Spots”. These measurements are for information purposes only and currently provide little scientific guidance.
There is suspicion that elevated levels may have long term health effects and may affect biological growth although no current guidance is available.

Radiation is a reported cause of increased ascospore release [68-71]

Where or if levels are elevated the source is identified and efforts to minimise may be required by specialists

3 Radiation fields compared 20.6 ambient to 5,996 upstairs desks with Router and wifi



Temperature and humidity on their own are worthless measurements in a water damaged property. This example shows 95% humidity in the Arctic and this is bone dry

6.7. The mold surveyor

This surveyor will search for mould with various techniques but care must be taken in identifying the correct protocols or sampling hypothesis.

Mould sampling should only be undertaken after an onsite investigation and a sampling hypothesis has been developed.

Typical sampling protocols may include:

- Viable and non-viable or dormant spores
- Spore fragments and mycelia
- Genus and or speciation
- Airborne
- Settled
- Intrusive and interstitial cavities
- Dust
- QPCR-DNA

Some sampling techniques which are semi quantitative and have very limited worth except for monitoring decontamination progress include, Mycometer and Intascope or Mould Scope. These fail to speciate or provide risk or hazard data.

6.8. The Remote Desk Top survey by IEP

This surveyor undertakes a risk and hazard assessment by phone and live video link and reviews recorded information without actually visiting the property and provides a risk based report with recommendations.

The survey may incorporate any or all of the following:

- Interview with the client to assess health impact and severity (not diagnosis)
- History of building occupant illness
- Building damage and or repair and improvement issues
- Review of any documents and data (previous water damage etc)
- Video link walk through of the property with focus on high risk issues

The objective is to provide the client with a low cost risk and hazard assessment based on the information gathered. The benefits are the input from experienced surveyor who will often identify building and construction defect hidden in plain sight. The report should enable the client to make immediate improvements where defect has been identified and this may include remediation and decontamination advice.

6.9. The Indoor Environmental Health Professional surveyor

The IEH will not undertake an inspection or assessment until he has gathered enough facts to develop an investigation and sampling hypothesis. The client's health issues must be taken into account when designing an inspection or investigation hypothesis. Generally speaking water or moisture damage can result in up to 30 different types of contaminates as listed below in Table 4 as identified in the consensus document [12] It should be recognised that even the best investigation is worthless if medical support is inadequate, therefore before engaging a professional IEH ensure a

suitably trained medical practitioner has been engaged. The IEP will be impartial, independent and most importantly qualified and competent.

Range of toxins, inflammagens, and microbes found in WDBs		
Mycotoxins[5]	Gram-negative bacteria[11,13,14]	Hemolysins[7,11]
Bioaerosols[6]	Gram-positive bacteria[11,13-15]	Proteinases[7,11]
Cell fragments[7]	Actinomycetes[16]	Chitinases[7,11]
Cell wall components[7]	Nocardia[11]	Siderophores[7]
Hyphal fragments[8]	Mycobacteria[17]	Microbial VOCs[20-21]
Conidia[8]	Protozoa[18]	Building material VOCs[20]
Beta Glucans[7,9]	Chlamydia[18]	Coarse particulates[11]
Mannans[10,11]	Mycoplasma[18]	Fine particulates[11]
Spirocyclic drimanes[7]	Endotoxins[11,13]	Ultrafine particulates[24-25]
Inorganic xenobiotics[12]	Lipopolysaccharides[13]	Nano-sized particulates[24,25]

Table 4 Contaminates from Surviving Mold consensus document [12] which may affect occupant health

The sampling hypothesis

Prior to undertaking any investigation a sampling and investigation hypothesis must be developed and this will revolve around many parameters but importantly must include:

- Recognised symptoms and extent
- History of health and possible links to building related illness
- Current diagnosis and medication
- Visual Contrast Test [15] (optional)
- Immune response issues (chemotherapy treatments etc)
- Doctors opinion, input and or requirements

Once the relevant factors have been assessed the IEHP will develop an investigation and sampling hypothesis (if required) to reflect the client needs and budget.

Objectives will vary but will often include the identification of:

- Historic issues and assessments
- Building or construction/design defect
- Cause of contamination, location and degree
- Type of contaminates present and possible synergistic effects
- Water damage issues
- Spread and possible reservoirs of contaminates
- Remediation issues
- Decontamination advice for surfaces
- Air pathways
- Air decontamination
- Third party Surface and air clearance certification

7. Typical survey results depending on who instructed surveyor or surveyor type.

While each report may focus on different solutions, each may be useful but not all necessary. Where goods, products, services may be linked to the surveyor, a conflict of interest may exist and if so, should be declared by the surveyor.

8. Typical Mold measurement and failure issues

The following section explains some of the typical measurement protocols and their shortfalls when used inappropriately. Inappropriate testing protocols when used in isolation are expensive and often worthless in terms of risk assessment or mould identification. Information in the following sections will explain why individual sampling protocols used in isolation are rarely appropriate and why a meaningful investigation will usually rely on many different appraisal techniques and skilled interpretation. The protocols and equipment shown in this section were developed by manufacturers who sell the virtues of the process. The results almost always comply with the manufacturers stated expectations, but the results cannot be used as they are not recognised in the scientific community or comply with any standards or recognised measurement criteria.[73]

8.1. Mycometer

The Mycometer is shown in photo 4. Mycometer and their agents train the technician during a one day course. The resultant report is a red green and amber traffic light appraisal for air and surface sampling. The traffic light appraisal cannot identify genus let alone species. The manufacturers state the product was tested by US government EPA through their Environmental Technology Verification Report [41.] The report states it provides semi quantitative appraisal of bio mass present. The report goes on to explain the use as a tool for monitoring progress during clean up and remediation process [40-41] The Mycometer cannot identify genus or species therefore risk and hazard assessments are impossible. [40-41,73]

This in effect means high seasonal levels of normally present environmental moulds can be misinterpreted as a hazard (red) and more importantly low levels of toxic mould seen as safe or green.

The Mycometer on site lab analysis cannot provide useful information in risk or hazard assessment but may be useful for assessing cleaning and source removal

Photo 4 The Mycometer

8.2. Instascope and Mouldscope Photo 5

This is real time analysis which provides a rank order bell curve interpretation. Unfortunately the bell curve data is made up of limited historic data of different countries and different times of the year and of course different building types and environmental conditions, plus differences in the target property areas. This effectively is comparison but not identification of contaminates outside the average counts. The bell curve cannot accommodate anything other than the central rank order distribution and unfortunately cannot recognise some of the more hazardous species individually, which may fall outside of average counts. The inside air is compared to outside air but cannot accommodate the shift in the multitude of variants which includes seasonal and barometric issues.

A concern here is that the outside air is disturbed while the inside air is tested without disturbance. This means the air sampling results are prone to false readings as spores and fragments may have settled.

More importantly the computer program assesses average counts and not specific hazardous (group 1) moulds which are generally accepted as being the toxic potentially species associated with water damaged buildings.[42]
The major concern is that so often the more toxic moulds form a very small part of the overall fungal ecology and this may easily fall outside the central “Average” count. See Fig 1 Another failure in this type of sampling is that air sampling is dependent on airborne particulates and of course settlement of spores and fragments will often result in negative results.[32-33-34-35-36]

5 The Instacope and Mouldscope (UK) can provide a risk assessment but rarely provide a hazard assessment and fails to identify risk and hazard

Fig 1 Showing typical Bell chart distribution but missing peripheral counts

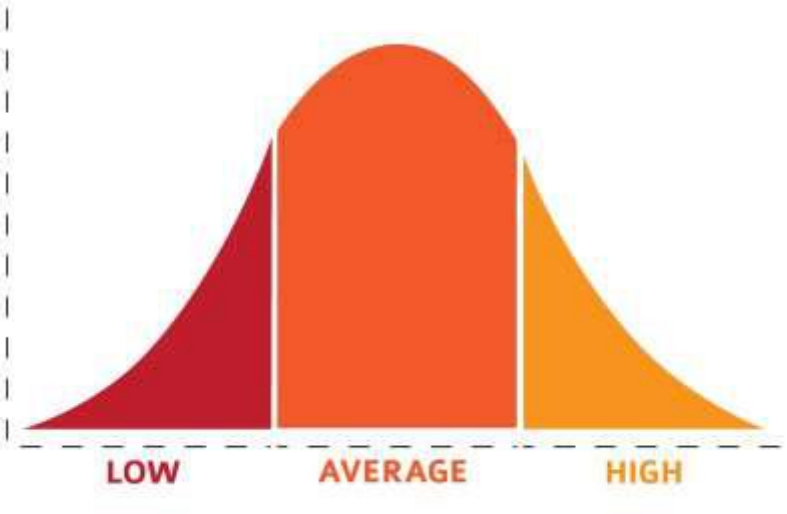


Fig 1 *The Instascope records only average counts and ignores the most important and usually lower counts of toxic moulds found in properties, where even single figures can be major indicators of health hazards*

9. Exposing the shortfalls in air and surface sampling

The Environmental Protection Agency (EPA) makes the following statements [43]

- *"Sampling for mold should be conducted by professionals with specific experience in designing mold sampling protocols, sampling methods, and interpretation of results."*
- *Sample analysis should follow analytical methods recommended by the American Industrial Hygiene Association (AIHA), the American Conference of Governmental Industrial Hygienists (ACGIH), or other professional guidelines.*
- *Inadequate sample plans may generate misleading, confusing, and useless results.*
- *For someone without experience, sampling results will be difficult to interpret. Experience in interpretation of results is essential.*
- *Sampling should be done only after developing a sampling plan that includes a confirmable theory regarding suspected mold sources and routes of exposure. Figure out what you think is happening and how to prove or disprove it before you sample!*

  This is known as hypothesis testing and Data Quality Objectives (DQOs) as mentioned by the EPA.[50]

Authors Note ref UK

While several references are made to USA guidance, it should be recognised the Health and Safety Executive (HSE) accept this guidance in the absence of UK equivalents

A most significant statement by the EPA [43]

"The results of samples taken in your unique situation cannot be interpreted without physical inspection of the contaminated area or without considering the building's characteristics and the factors that led to the present condition"

This of course means that any form of sampling can only be interpreted as part of a professional site investigation.

In the following Table 5 we see an example of Instatscope/Mouldscope survey. It appears at 2360 the outside has almost 4 times the airborne mould spores per cubic meter against an average inside value of 600.This is meaningless without speciation.

In the Table 6 we see the results of the Mycometer survey again coloured chart which has absolutely no international or national acceptance or meaning.

In Table 7 we see the survey results from Mould score of a swab and or culture based analysis with CFUs as the only analysing criteria which is meaningless other than high or low what?

In Tables 5-6-7 the assessments and results are displayed in colours. You will of course realise there are no risk or hazard values in colours in fact there is even limited value in numbers without knowledge of species.

In table 7 the results are of viable counts and of course cannot include the more hazardous non-viable fragments or mycelia.[37] Speciation is unlikely to be undertaken by the lab in low cost culture based sampling.

You will also appreciate that without species and other valuation, absolutely no useful data was provided with these surveys in terms of Building Related Illness which could be used to assess vulnerabilities of CIRS patients or even identify risk [23].

Most importantly the significance of this statement can be seen in the Quantitative PCR (ERMI) analysis in Tables 10 & 11 You will see group 2 moulds are recognised as normal environmental moulds while the Group 1 targets specific and potentially toxic moulds associated with water damage. In the ERMI calculation the group 2 moulds are taken away or actually ignored in the ERMI score. Without speciation almost all mould sampling is irrelevant.

InstaScope

3 of 6

Mold Inspection Report

SCAN-BY-SCAN MOLD COMPARISON

The graph below displays how each room compares to other rooms, to the outside air, and to the total house average on the day of the test. Comparison of these values is one part of the logic InstaScope uses to determine whether a room is green, yellow, or red.

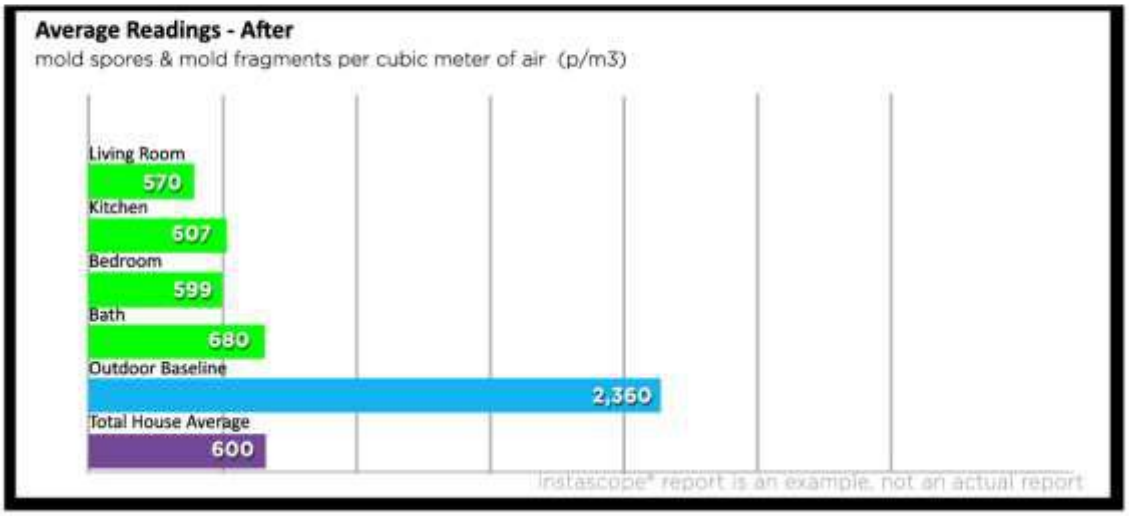


Table 5 Mould Scope UK

Mycometer®-air

Quantification of mould/fungi in air in non-ventilated buildings

Project Name	REDCATED	Measured Standard Value	495
Location		Instrument is calibrated — Instrument Standard Value	495
Collected by		Ambient temperature for analysis (between 18-30 C)	19.5
Analysis date		Reaction time (min:sec)	37:55

Sample ID/No.	Sample Location	Sample Date dd/mm/yyyy	Flow Rate (LPM)	Sample Time (Mins)	Sample Volume (m3)	Blank Value (BV)	Sample Analysis (AV)	Mycometer Air Value (MAV/m3)	Result Category
1	Lounge - Under floor void	15/05/2015	20.0	15	0.30	70	99	97	A
2	Lounge	15/05/2015	20.0	15	0.30	70	188	393	A
3	Kitchen	15/05/2015	20.0	15	0.30	70	110	133	A
4	Hallway	15/05/2015	20.0	15	0.30	70	183	377	A
5	Back bedroom	15/05/2015	20.0	15	0.30	70	233	543	A
6	Main Front bedroom	15/05/2015	20.0	15	0.30	70	245	583	A
7	Small front bedroom/child's dressing room	15/05/2015	20.0	15	0.30	70	216	487	A

Suggested Interpretation Categories for Aggressive Air Sampling in non-ventilated buildings

A	MAV <900 represents a typical environment
B	900 < MAV ≤ 1700 represents an atypical environment
C	MAV > 1700 represents a contaminated environment
BDL	Below detection limit

Table 6 Mycometer

MOULDCHECK

MOULDCHECK SETTLE PLATE:

Plate Number	Location	Fungal Count cfu/m³	Species Breakdown	Category
CG1	Wine Cellar	1,480	1,460 x Penicillium sp. 20 x Aspergillus sp.	VERY POOR
CG2	Kitchen	30	30 x Penicillium sp.	GOOD
CG3	1st Floor Bedroom - Front	60	60 x Penicillium sp.	GOOD
CG4	1st Floor Bedroom - Rear	80	60 x Penicillium sp. 20 x Mucor sp.	GOOD

Table 7 Absolutely no technical measurement in swab or culture dish CFU counts

10. Recognising shortfalls of air and surface sampling with culture based methods

The mould surveyor may use culture plates in either an air sampling vacuum pump or use them to collect spores which drop onto them. An alternative to this will be a swab sample, where a swab is wiped across a suspect surface or at random and this is transferred to a culture dish.

There are failures in all these methods and World Health Organisation (WHO) state they have serious limitations [10]. These limitations are recognised as:

- Culture plates cannot grow dead (non-viable) dormant or fragments of mould or mycelia, which according to WHO are 40 times more hazardous than whole spores [37]
- Culture plates should use a variety of different growth media to accommodate the different mould growth requirements (British and International standards 16000 1-19) One plate doesn't fit all) so the cost can be very high.
- Dominant species can overlay and obscure slow growing species [44]
- Typical Rodac (convex plates) should use DG-18 or MEA agar [16]

Culture based sampling must recognise the different growth requirements of specific molds.
Some agars may also require suppression additives to control competing bacteria growth.[18]

The following are limited examples of agars and suppression to be considered:

- ***Saprophytic fungi*** Malt extract agar with Rose Bengal or chloramphenicol
- ***Xerophilic saprophytic fungi*** Malt- Salt agar EA with Dichloran glycerol (DG-18)
- ***Stachybotrys chartarum and Memnoniella echinata*** *Cellulose agar*

Many agars typically used are rich in carbohydrates which favour rapidly growing species only[18] The mould report will provide a very limited and inaccurate picture which provides almost no real information to assess possible risk of mould contamination other than in the areas sampled, which of course excludes the majority of risks from non-viable spores, fragments and mycelia etc [37]

Surface sampling should always be a combination of different protocols[16]

6 Culture (settle) plate and SAS pump for culture based air sampling results have serious limitations [10]

11. Example of typical poor mould report

In the following table (8) viable spore traps (culture dishes) were used around a room to assess mould contamination. The lab results show Colony Forming Units (CFUs) that the inside of the property is much cleaner than the outside ambient. The reality is absolutely no conclusion could be made from this analysis because from further testing we confirmed:

The outside must be considered as normal with all group 2 moulds
F3 sample (Lounge) which initially looked the lowest was found to be contaminated with:

- Aspergillus *fumigatus (60cfu)* [45]
- Penicillium *brevicompactum (130) (an immunosuppressant)*

Culture based sampling without speciation cannot assess risk or hazard[23]
Culture based sampling does not identify fragments which are the highest mould hazard.[37]

Sample Ref	Location	Type	Concentration CFU*	Identification
F1	Bedroom 1	Viable spore trap	350 150	Penicillium *sp* Aspergillus sp
F2	Bedroom 2	Viable spore trap	290 150	Penicillium *sp* Aspergillus *sp*
F3	Lounge	Viable spore trap	60 130 450	Aspergillus *sp* Penicillium *sp* Cladosporium
F4	Ambient (outside)	Viable spore trap	400 200 2000	Penicillium *sp* Aspergillus *sp* Cladosporium

Table 8 *Colony Forming Units

12. Total Spore Counts

In this air test, air is pulled through a sampling cassette at a specified but variable rate dependent on air debris loading (measured separately) This type of sampling is recognised as having limitations and therefore should only be undertaken by someone who understands these issues. [18-33-34-35-36-38] This sampling is economical and can identify risk areas when used with other investigation criteria and may be seen as an initial investigation protocol [10] There is a high variability of results and this can be due to many factors, some of which can be reduced by careful assessment and most importantly using qualified and ISO approved laboratories. Comparison can be made between inside and outside air conditions (spore types and levels), however there are many issues which can make this very unreliable[65].Consideration should be made regarding the cassette “Cut” which specifies a considered point of capture for various sized spores in micron.

When taken in context, the total spore count lab results can provide very useful information to the professional IEP. See for example section 16 and comparison to ERMI [47]which is a Quantitative Polymerised Chain Reaction (QPCR-DNA) and provides speciation. The WHO suggest Total Spore counts may be a first choice in any investigation following the development of the testing hypothesis.[10]

7 Air sampling for Total Spore Counts

13. ERMI and Quantitative Polymerised Chain Reaction (QPCR) [47]

The ERMI sample is analysed by QPCR-DNA and identifies whole spores, fragments and mycelia of target moulds which are divided into two groups (1 and 2).

Group 1 moulds

These are recognised as the moulds which grow in water damaged buildings and are capable of causing negative health impact and production of mycotoxins. These moulds are present but usually below detection levels in ambient air.

Group 2 moulds

This is a smaller group of normally present moulds found both inside and outside (ambient) conditions. Although not believed to be toxic they are of course allergenic as are all moulds.

The lab analyses the 5mg dust sample into two distinct groups and makes complex calculations. The two groups are 1 and 2. Group 2 is taken from group 1 to provide the ERMI score. This is called the Relative Mould Index (RMI) and reflects the percentage of 1096 homes sampled in USA. Typical ERMI assessment can be seen in Tables 10 & 11 and they show depending on where samples are taken, the results vary, and therefore multiple sampling may be required.
The original ERMI study did not compare the score with health impact comparison between highest and lowest scores The sickest people in the study could have had a score of minus 2 or 10 but they were not recorded.

In the Journal of Occupational & Environmental Hygiene the ERMI score was compared to occupant health issues such as wheeze and the authors found no *statistically significant* difference between children with and without wheeze [46] although further studies have provided additional risk assessment [49] Therefore judging an ERMI score as an indicator of health risk is not recommended. Of course the ERMI QPCR data can be much more useful when assessing the presence of potentially toxic moulds and interpretation into HERTSMI 2 [23]

Table 5

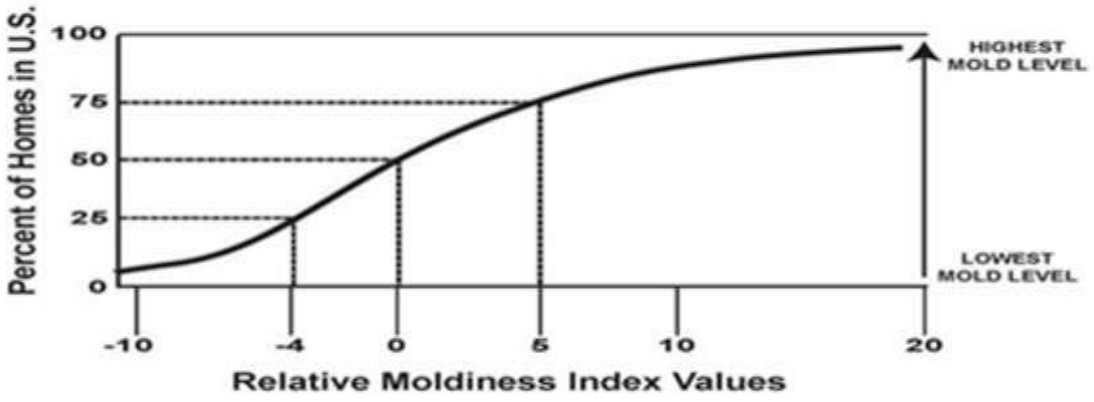


Table 9 Showing the Mold Index against 1026 properties in USA

14. ERMI as a significant tool (QPCR)

The speciation of group 1 and 2 moulds from the lab analysis is extremely important where it identifies the group 1 Toxic moulds*

**moulds which can but do not always produce toxins*

Table 10 below shows typical lab analysis of collected dust and with an ERMI score of 23 and this sampled area was extremely contaminated although visibly clean. This result when reviewed on Table 9 would be seen as extremely important in the assessment of health impact of building related illness in this property but there is a major concern here.

In Table 11 we see an ERMI score of ZERO and the spore count equivalent in the low hundreds and double digits. The concern here is that this sample (Table 10) was taken in a room next to sample (Table 11)

There was no visible mould in either of the adjacent rooms although builders had recently removed the bath and plasterboard walls because of a “minor” leak

9 The source of dust for ERMI sample (Table10) (post builders clean)

15. ERMI [47] sampling general errors

The example of Table 10 and 11 where major differences were identified in two adjacent rooms is a major concern. While ERMI is a very important tool, it is clear how to use it properly, is of paramount importance.

Note the supporting evidence of this survey with the total spore count in Table 12 samples 2 and 3 WC and master bedroom which correspond to the ERMI samples in Tables 10 and 11.

Table 10

8/10/17
1771229

Results:

Group 1 Water Damage Indicators Fungal ID	Sample ID Dust Weight 5 4.9 mg	
	SE*	SE/mg
Aspergillus flavus	6	1
Aspergillus fumigatus	190	39
Aspergillus niger	42	9
Aspergillus ochraceus	ND	<1
Aspergillus penicilloides	78	16
Aspergillus restrictus	290	59
Aspergillus sclerotiorum	10	2
Aspergillus sydowii	230	46
Aspergillus unguis	1	1
Aspergillus versicolor	380	77
Aureobasidium pullulans	2600	530
Chaetomium globosum	2600	530
Cladosporium sphaerospermum	16	3
Eurotium (Asp.) amstelodami	9900	2000
Penicillium variabile	310	63
Penicillium brevicompactum	5300	1100
Penicillium corylophilum	770	160
Penicillium crustosum (Group 2)	2300	460
Penicillium purpurogenum	8	2
Penicillium spinulosum	ND	<1
Penicillium variabile	24	5
Scopulariopsis brevicaulis	3400	690
Scopulariopsis chartarum	55	11
Stachybotrys chartarum	5	1
Trichoderma viride	1500	320
Wallemia sebi	10	2
Sums of the logs	36.0	

Group 2 Common Indoor Molds Fungal ID	Sample ID Dust Weight 5 4.9 mg	
	SE*	SE/mg
Acremonium strictum	2	1
Alternaria alternata	18	4
Aspergillus ustus	23	5
Cladosporium cladosporioides-1	19000	3900
Cladosporium cladosporioides-2	34	7
Cladosporium herbarum	2200	450
Epicoccum nigrum	78	16
MucorRhizopus	9	2
Penicillium chrysogenum-2	9500	1900
Rhizopus stolonifer	2	1
Sums of the logs	13.1	

* SE = Spore Equivalents, ND = Not Detected

Sample	5
ERMI Calculation	36.0 – 13.1
ERMI Result	23

Table 11

8/10/17
1770410

Results:

Group 1 Water Damage Indicators Fungal ID	Sample ID Dust Weight 6 5.2 mg	
	SE*	SE/mg
Aspergillus flavus	ND	<1
Aspergillus fumigatus	8	2
Aspergillus niger	2	1
Aspergillus ochraceus	ND	<1
Aspergillus penicilloides	1	1
Aspergillus restrictus	27	5
Aspergillus sclerotiorum	ND	<1
Aspergillus sydowii	ND	<2
Aspergillus unguis	ND	<1
Aspergillus versicolor	ND	<1
Aureobasidium pullulans	520	100
Chaetomium globosum	1	1
Cladosporium sphaerospermum	3	1
Eurotium (Asp.) amstelodami	510	97
Penicillium variabile	ND	<1
Penicillium brevicompactum	24	5
Penicillium corylophilum	ND	<1
Penicillium crustosum (Group 2)	ND	<1
Penicillium purpurogenum	ND	<1
Penicillium spinulosum	ND	<2
Penicillium variabile	ND	<1
Scopulariopsis brevicaulis	4	1
Scopulariopsis chartarum	3	1
Stachybotrys chartarum	ND	<1
Trichoderma viride	5	1
Wallemia sebi	1	1
Sums of the logs	5.6	

Group 2 Common Indoor Molds Fungal ID	Sample ID Dust Weight 6 5.2 mg	
	SE*	SE/mg
Acremonium strictum	ND	<1
Alternaria alternata	3	1
Aspergillus ustus	ND	<1
Cladosporium cladosporioides-1	3100	590
Cladosporium cladosporioides-2	4	1
Cladosporium herbarum	1500	290
Epicoccum nigrum	17	3
MucorRhizopus	4	1
Penicillium chrysogenum-2	6	1
Rhizopus stolonifer	ND	<1
Sums of the logs	5.8	

* SE = Spore Equivalents, ND = Not Detected

Sample	6
ERMI Calculation	5.6 – 5.8
ERMI Result	0

Client: Hazmat Response
C/O: Jeff Charlton
Re: Sissy

Date of Receipt: 08-04-2017
Date of Report: 08-07-2017

SPORE TRAP REPORT: NON-VIABLE METHODOLOGY

Location:	1: Kitchen				2: WC Up				3: Master Bed				4: Ambient			
Comments (see below)	A				B				None				None			
Lab ID-Version‡:	8277391-1				8277392-1				8277393-1				8277394-1			
Analysis Date:	08/07/2017				08/07/2017				08/07/2017				08/07/2017			
Sample volume (liters)	30				30				30				30			
Background debris (1-4+)††	3+				3+				3+				2+			
	raw ct.	Count/m3	DL/m3*	%	raw ct.	Count/m3	DL/m3*	%	raw ct.	Count/m3	DL/m3*	%	raw ct.	Count/m3	DL/m3*	%
Hyphal fragments					4	130	33	n/a	1	33	33	n/a				
Pollen	1	33	33	n/a									2	67	33	n/a
§ TOTAL FUNGAL SPORES	71	5,800	n/a	100	127	10,000	n/a	100	45	4,500	n/a	100	99	13,000	n/a	100
Alternaria									1	33	33	1				
Ascospores	3	400	130	7	3	400	130	4	7	930	130	21	10	1,300	130	10
Basidiospores	10	1,300	130	23	3	400	130	4	7	930	130	21	15	2,000	130	15
Chaetomium					12	400	33	4	13	430	33	10				
Cladosporium	19	2,500	130	44	6	800	130	8	2	270	130	6	72	9,600	130	73
Epicoccum	1	33	33	1									1	33	33	< 1
Other brown									1	33	33	1				
Penicillium/Aspergillus types	37	1,400	39	25	103	8,400	82	81	14	1,900	130	41	1	130	130	1
Smuts, Periconia, Myxomycetes	1	33	33	1												
Stachybotrys																
Ulocladium																
Zygomycetes																

Comments: A) 35 of the raw count *Penicillium/Aspergillus* type spores were present as a single clump. B) 53 of the raw count *Penicillium/Aspergillus* type spores were present as a single clump.

Table 12 Note samples 2 and 3 correspond with the ERMI results in Tables 10 & 11

16. ERMI lab analysis used to calculate HERTSMI 2 [23]

The HERTSMI 2 calculation identifies three ranges of risk to the CIRS patient:

- Statistically safe to re-enter a building
- Borderline
- Dangerous for those with CIRS to enter

The calculations should only be applied to properly diagnosed CIRS patients. Absolutely no other risk or hazard assessment can be applied from this formulae and improper application of HERTSMI 2 can result in unnecessary and possibly high risk exposure.

17. General Investigation failures

Typically a survey should be a risk and hazard assessment which will provide the client and medical profession with an overview of environmental conditions and imbalances. Generally the more types or differing sampling, the more information is gathered but this should only be advocated following the development of a sampling hypothesis and Data Quality Objectives [50] Unfortunately this can be expensive and a balance of cost and risk must be pursued.

Of course whether a property is contaminated with one or more toxic substances the end result will be the same, remove the cause, remove the contamination and this will usually be the same whatever the levels or types and multipliers. This often means once any form of contamination or causation is established, the survey has been successful. Limitations to this do exist and the sampling hypothesis which should be established prior to the survey will dictate outcome requirements.

18. Surface contamination measurement with Adenosine Tri Phosphate (ATP)[51]

ATP testing is often used as a measurement of cleanliness or decontamination. Indeed ATP swab testing can be used as an indicator of surface cleanliness or biological material present, although it cannot distinguish between mould and bacteria, live, dead or indeed different organic soiling.[74] Unfortunately the technology was developed and indeed sold to assess comparison of cleaning efficacy from previous cleans and not to identify cleanliness. The technology was specifically aimed at hard non porous surfaces typically found in food preparation areas.

The use of cotton swabs on soft or uneven surfaces will see a loss of swab and detritus which will affect the sample size. The readings are not considered as an accurate assessment of overall contamination but some may use to verify compliance to IICRC condition 2 as found in IICRC S520 requirements and materials should have moisture content less than 15%. Condition 2 is settled spores but of course ATP analysis cannot distinguish between bacteria, mould and therefore speciation and risk assessment is impossible. An area of 4 square inches is swabbed and the swab is inserted into a luminometer which reads levels of the reaction luciferase which emits light in ranges according to the levels of contamination and this is reported as femtomole of ATP in terms of light (Relative Light Units). ATP is an indicator which may indicate the need for further testing.

Obviously a low RLU on a surface contaminated with hazardous organism could show clean against higher RLU of a low risk contaminate.

Table 13 shows typical results when used as a measurement for condition 2 but the limitations are obvious.

Swab testing result	Condition	S520 standard	Reading RLU	Interpretation
1-50	1	Normal Fungal Ecology		Pass
50-150	2	Settled Spores		Caution
>150	3	Actual Growth		Fail

Table 13 Using ATP to typically comply with IICRC S520 [74]

Note ATP will not distinguish differences between non-viable or dead components of mould or bacteria or indeed differentiate between organic materials

Fig 2 shows the process of swabbing and the results can be seen in minutes

Fig 2 Showing the ATP sampling process and analysis meter

19. Psychometrics and false readings

Psychometrics is the science of moisture transfer in the air. There is a belief that mould for example won't grow under 75% humidity and 77F or 25 degrees centigrade, however different moulds require differing environments.

Some molds prefer relatively dry conditions xerophiles, while some prefer wetter conditions known as hydrophilic. Equally some moulds prefer higher temperatures but then some grow in refrigerators.[52-53] Should we be challenging the use of home humidity and temperature sensors and measurement techniques as seen in photo 11?

10 The author in the Antarctic where temperatures can tumble to -22F -30c the humidity was 90% but no mould anywhere?

The explanation regarding high relative humidity but dry conditions can be seen on the Psychrometric chart in Table 14.Temperature and humidity on their own are of no significant use when assessing risk of mould growth or water damage. At -10c the Antarctic air can only transport .002 grams of moisture per kilogram of dry air

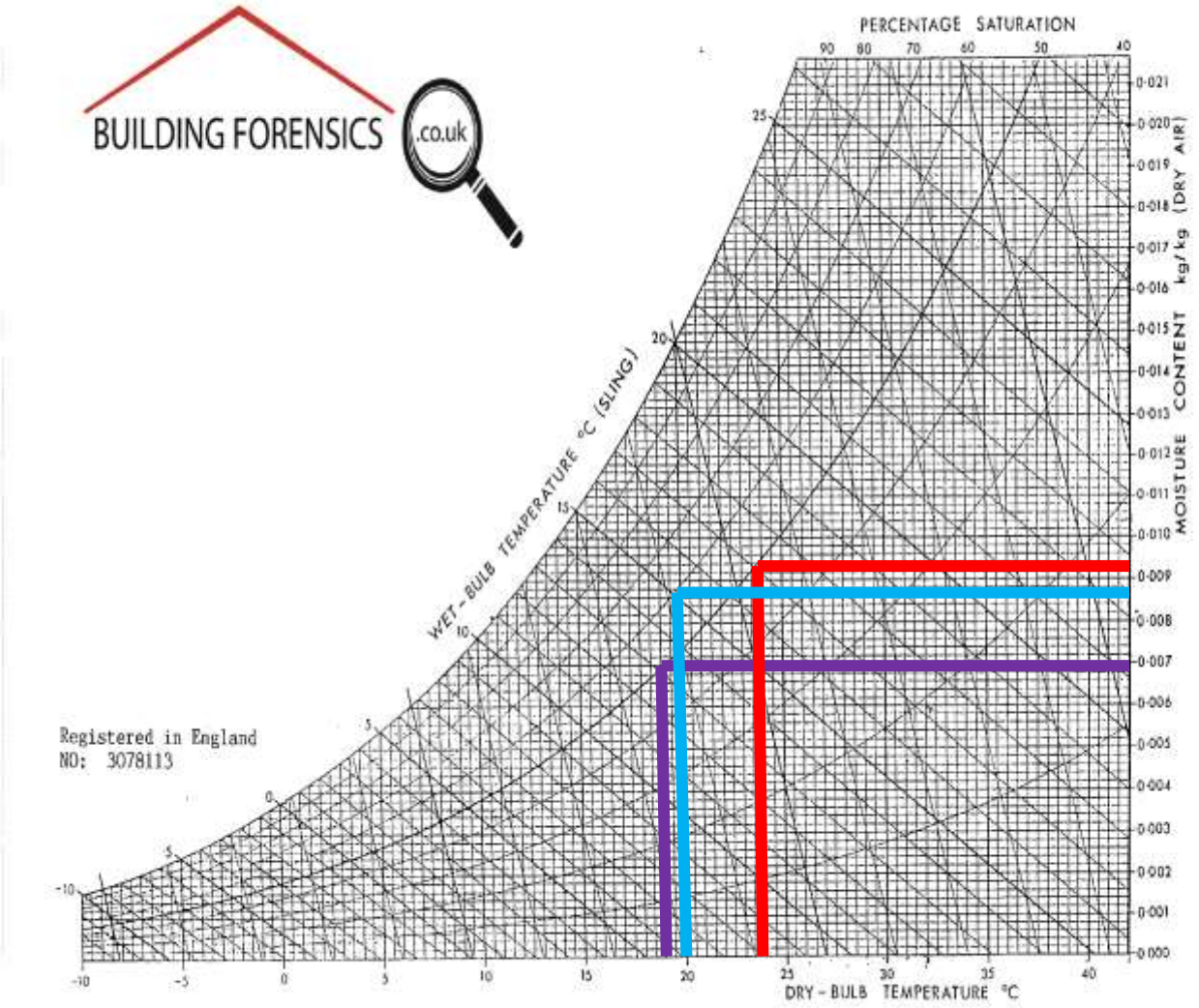
In Table 14 below we see that Rh is a worthless measurement without temperature and more importantly the calculation of air moisture , (known as specific humidity) as calculated on the “Psychrometric chart” It can be seen the higher the temperature the more moisture air can hold, but equally the lower the temperature the less moisture can be carried.[54] This means simply raising the temperature will reduce relative humidity as the heat causes the air to expand and increases its capacity to hold moisture.

Author Note *this is a simplistic explanation of humidity as air cannot technically hold moisture*[54]

Dew point condensation,(DPC is the physics behind a dehumidifier. The dehumidifier pulls warm moist air into the machine which passes over a cooling coil. The drop in temperature causes Dew Point Condensation and water literally falls from the moist air into the drip pan. Here we see lowering the temperature increases relative humidity until the air reaches a saturation point and releases the held moisture.

In the home DPC occurs were the normally present moisture in the air meets a cooler surface which is usually less insulated and or ventilated and the water literally falls out and condenses on the cooler surface often with resultant, localised mould growth.[3-54]

Table 14



24c @50% Rh carries .000925 g/kg of moisture per kg of dry air Dew Point at 17c

19c@50 Rh carries .0007g/kg of moisture per kg dry air . Dew Point at 13c

See photo 10 20c @60% Rh 0087g/kg of moisture per kg of dry air (measured in grains per pound in USA)

Table 14

11 What is the value of this data?

20. Moisture mapping and the importance of EMC and Equilibrium Relative Humidity (ERH)

Moisture mapping correctly is essential if the cause of moisture and resultant biological amplification is to be traced. There are international standards for moisture measurement in different materials and using different measurement techniques. A moisture mapping survey cannot usually be undertaken with a simple moisture meter as often used by building surveyors which is known as a wood moisture equivalent meter (WME). A conductive or radio meter as seen in photo 12

12 The conductive moisture meter is configured to calculate moisture content of wood only. Table 15 next provides a very rough comparison for other materials.

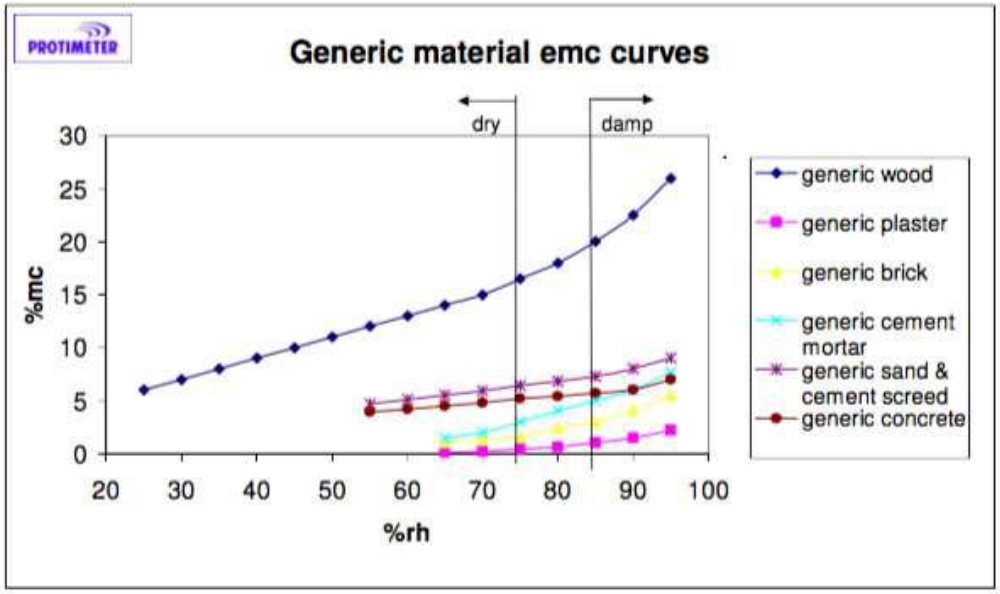
Structural material	MC	WME%	ERH
Wood	16	16	N/A
Drywall	3.0	12	N/A
Plaster	0.3	15	N/A
Brick	1.5	15	75
Concrete	3.5	15	75
Sand cement screed	6.0	15	75

Table15 Comparison of building materials against the Wood Moisture Equivalent (WME) meter [55]

13 You cannot hammer delicate moisture pins into concrete or brick

The Table 16 below shows how Equilibrium Moisture Content (EMC) is used to measure the moisture content in materials (**Note** *NOT on the surface*)

Table 16 In table 16 it can be seen moisture content is measured in relative humidity between 75% and 85% EMC. (Dry and damp)



emc - equilibrium moisture content %mc - % moisture content %rh - % relative humidity	The given emc values are for guidance only. Precise emc curves are material specific; if required, they should be generated under laboratory conditions by the interested party.

14 This shows methodology of measuring EMC and ERH in concrete floors

21. The importance of EMC, a_w, U - R values and Dew Point Condensation (DPC)

If we took a bottle of coke and a box of eggs out of a fridge into a warm room we would see the coke bottle sweat but no visible change in the egg box. Both are at the same temperature but different materials respond differently depending on porosity and heat transfer qualities. The reason is dew point condensation occurred on the non-porous bottle but although the egg box was the same temperature, the moisture was adsorbed and increased the EMC.

The obvious analogy is the environmental conditions as shown in photo 11 of 20c at 60% Rh. The air and DPC may be a low risk if the whole room was homogenous in temperature, insulation qualities and porosity of materials but some areas like corners and behind furniture, wall pictures may be at lower temperatures and more porous which can result in DPC. This can occur in interstitial cavities and generally hidden due to construction design /build defect .[16-56-57]

Equally thermal conductivity of different construction materials can mean DPC in a single room can vary (Heat Transfer) measured as U value in "K" m²/W [58 p19]
b\
Low thermal conductivity is equivalent to high insulating capability (resistance value) Therefore in moisture mapping survey it is important to understand the risk of different materials and even more importantly how they were installed. The infra-red photo number 39 shows the effectiveness of cavity insulation except where the contractors failed to install it properly, resulting in DPC to isolated areas of wall.[56]

15 Same temperature but different response to dew point condensation

Insulation *U* and Thermal resistance *R* values

The rate of heat loss from a building element is usually specified in terms of the thermal transmittance or *U* Value.
The converse to *U* value is *R* value which is thermal resistance and this applies to each layer of construction material.[58]

Table 17 shows typical *U* values of construction materials when dry. All permeable porous materials will see *U* values increase when wet because of increased conductivity thereby increasing DPC risk
Penetrating rain or rising damp and even interstitial condensation may increase *U* value which can reduce dew point temperatures, perpetuating the issue. [59]

Material	U Value
Solid brick wall	2
Cavity wall	1.5
Insulated wall	0.18
Single glazing	4.8 to 5.8
Double glazing	1.2 to 3.7
Triple glazing	1
Solid timber floor	3

Table 17

It is important to realise that although U values are awarded at the point of laboratory testing, poor design and construction defect can dramatically alter thermal efficiency. Most importantly both *U* and *R* values can be altered by moisture often associated with interstitial dew point condensation[58] and this can be caused by the misplacement or failure of the vapor barrier or vapour check [60] If we now apply this to mold growth we can see that the type and condition of any material can influence or be influenced by a_W and environmental factors [3-16]

23. Water activity and mould growth requirements
The development of mould and biological activity will depend on moisture at various levels and state and in particular the water activity, a_W
In table 18 we see the relationship between Relative humidity and Water activity

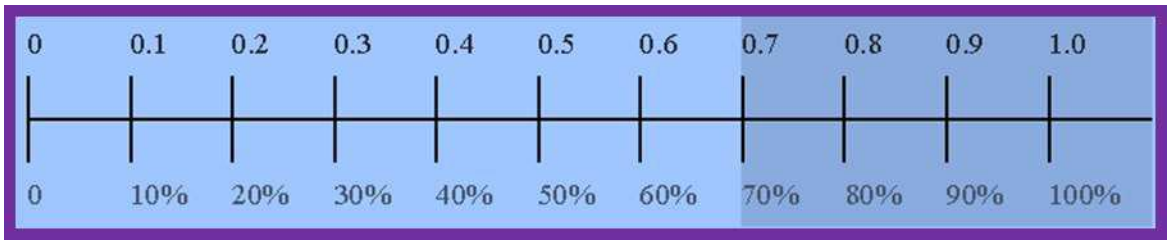


Table 18 **The correlation between RH and a_W**

24. The following table shows water requirements for active mould growth [53 68]
The differing water requirements should alert the surveyor to the complex issues of primary, secondary and tertiary growth

Coloniser group	a_w range	Classification	Species
Primary colonisers	<0.80	Xerophilic/Xerotolerant	Penicillium chrysogenum, Aspergillus *versicolor.* A *fumigatus.* A *niger,* A.*Sydowi* A.*ustus. Eurotium* spp. P.*brevicompactum,* P.*commune*, Wallemia sebi, *Paecilomyces variotti*. P.*palitans*
Secondary Colonisers	0.80-0.9	Mesophilic	*Alternaria spp,Cladosporium spp, Eppicoccum nigrum,Phoma spp,Ulocladium spp*
Tertiary colonisers	>0.9	Hydrophylic	Chaetomium globosum, Fusarium, Menoniella echinata, Rhizopus stolonifer, Stachybotrys chartarum,Trichoderma spp,

Table 19 Fungi Growth requirements surface humidity (a_W)

HERTSMI 2 a_W range

The HERTSMI 2 roster [23] shows a wide range of moisture requirements.

HERSTMI 2 Species	Specific range aW	Type	General a W Range	Colonisers
Aspergillus penicilloides	0.73 0.77	Extremely Xerophilic	<0.075	Primary
Aspergillus versicolor	0.78-0.79	Moderately Xerophilic	0.75-0.79	Primary
Chaetomium globosum	0.9	Hydrophilic	>0.90	Tertiary
Stachybotrys chartarum	0.94	Hydrophilic	>0.90	Tertiary
Wallemia sebi	0.69-0.75	Extremely Xerophilic	< 0.75	Primary

Table 20 HERTSMI 2 specific a_W growth requirements

24 An example of environmental misinterpretation

The following example is emphasised to highlight issues.

We can see from the environmental meter that room behind the wall is at low risk at 20c 60% Rh (photo 15). The IR scan shows temperature variations between 4.6 and minus 3.5c (photo 16)

We can see from Table 21 that Dew Point Condensation (DPC) will occur at 12 c Despite high internal temperatures DPC within the poorly insulated wall cavities of the drywall is inevitable, although no visible mould was present, air sampling confirmed tertiary mold growth emanating from cavities.

15 Room looks low risk

16 IR photos shows temperature range of cavity wall from -3.5 to 4.6c

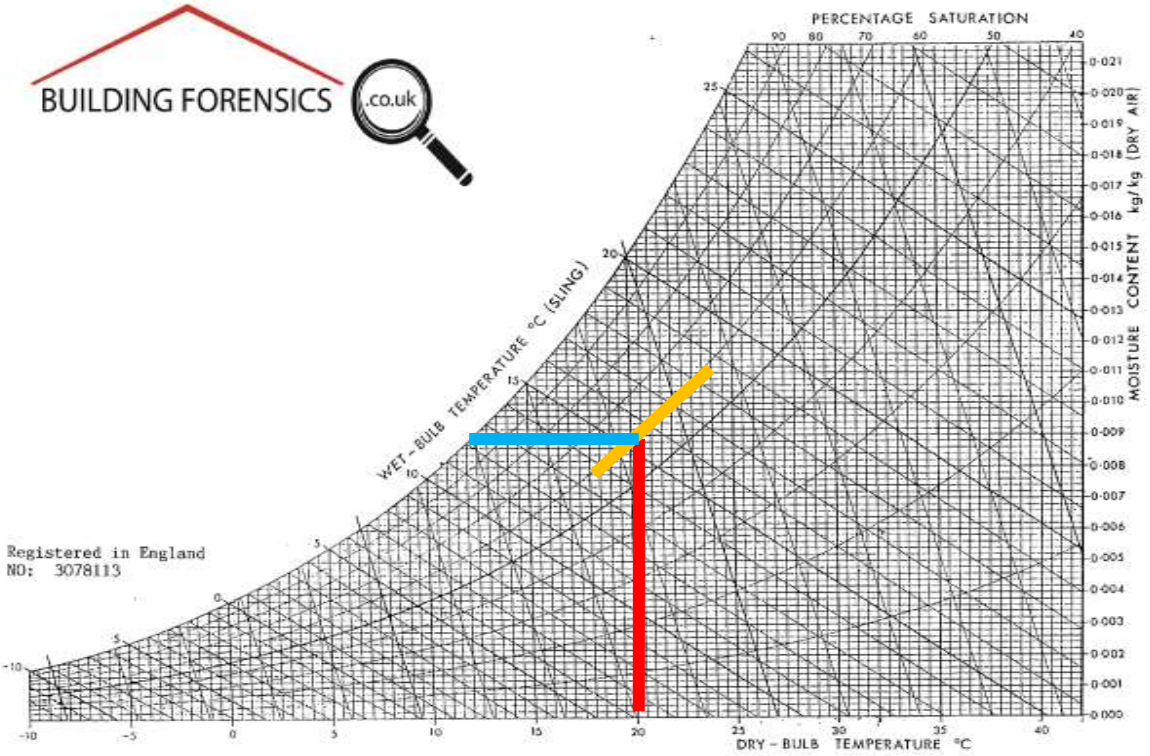


Table 21

Temperature 20c
Relative humidity 60%
Dew Point 12c

16 Misleading results

This section identifies examples of common mistakes and resultant false moisture content readings. These false readings can be due to a variety of issues but some of the most common mistakes are misinterpreting results from conductive materials or deposits:

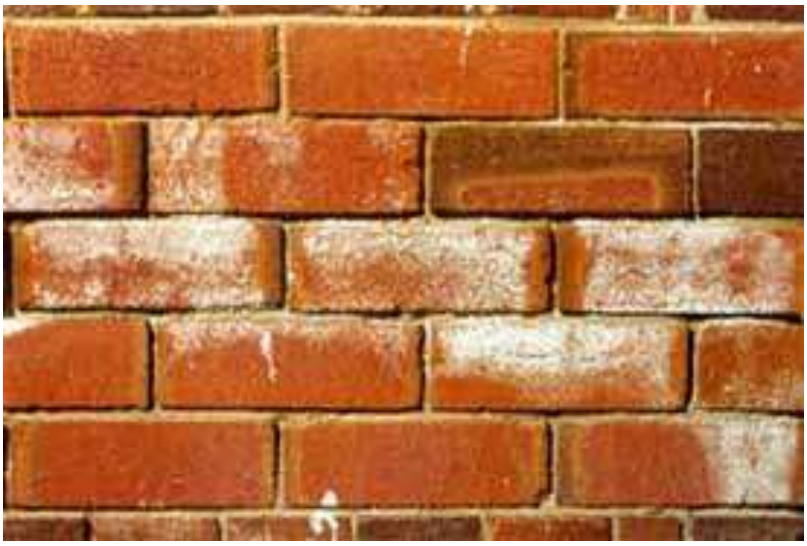
- Carbon rich materials can influence conductive and radio meters providing false results
- Lead paint on dry wood surfaces will show wet.
- Hygroscopic salts adsorb moisture from the air and can cause false wet readings on dry walls
- Hygroscopic salts such as Nitrates and chlorides from ground water can be confused with surface salts or surface hygroscopic materials [61]

- Bricks generally can be affected by sulphate and salt attack and this can lead to moisture damage and false diagnosis [58-60-61]

Some building materials have a high carbon content which causes high conductivity and false wet readings on conductive moisture meters

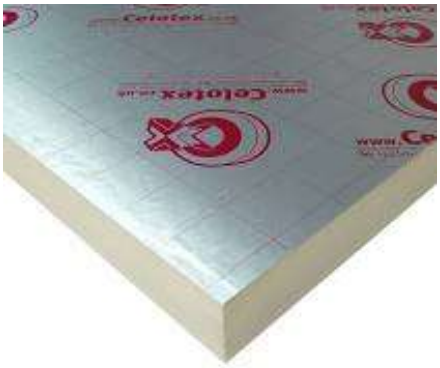
17 Cinder block with high conductivity due to high carbon content

18 Chloride and nitrate salts of sodium give false wet readings



19 Visible salts (efflorescence) are seldom hygroscopic and are usually sulphates

20 Tap water and central heating pipes can result in false wet readings



21 Foil backed insulation or drywall (plasterboard) give false readings

25 Conclusions of inspection failures

We have seen a short list of typical survey failures in preceding sections. These mistakes can have far reaching consequences in terms of deteriorating health or often unnecessary and costly repairs. While the preceding sections have shown industry failures, it should be recognised the information provided by even flawed protocols can be used when the shortfalls are understood and accounted for or indeed changed to eliminate the offending issues.

26 Walk through survey

The walk through survey is a first step and this is to assess possible construction or design defect and visible deterioration. Changes in building dynamics brought about by “improvements” and or material changes to air flow and insulation are often found to have unbalanced the original building design. Possible sources of contamination and reasons for poor Indoor Air Quality (IAQ) should be assessed and from this initial assessment a list of target areas identified.

22 The home environment may include bedding animals and possible cause of building related illness

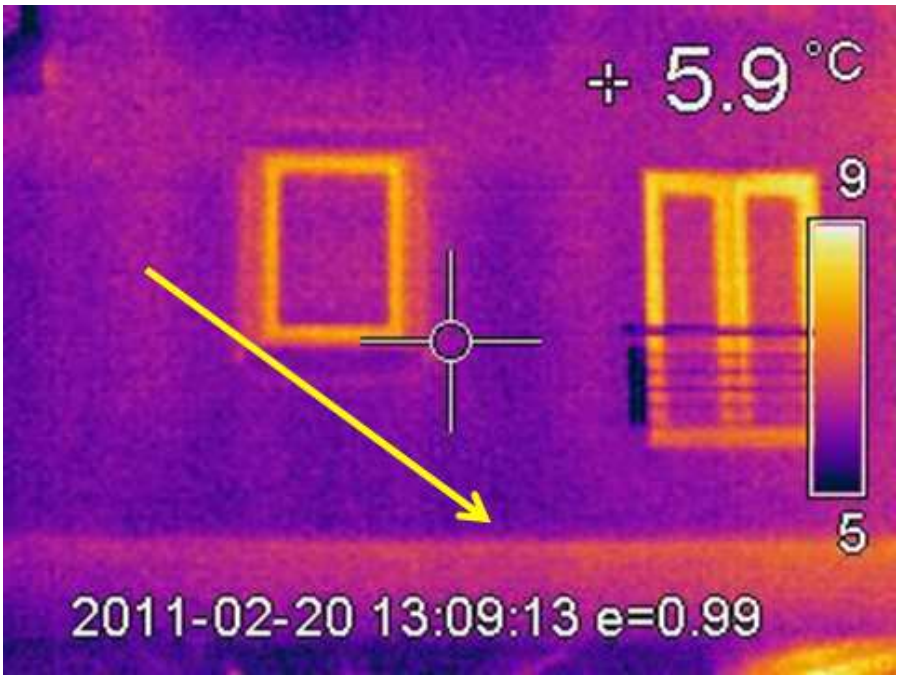
23 The rear of the bedside cabinet against a cold external wall resulting in DPC

24 The client without health issues didn't recognise the two bowls of tablets and inhalers was an indicator of health severity. The 12inch tile in the forground was saturated and fell from the ceiling durng the inspection

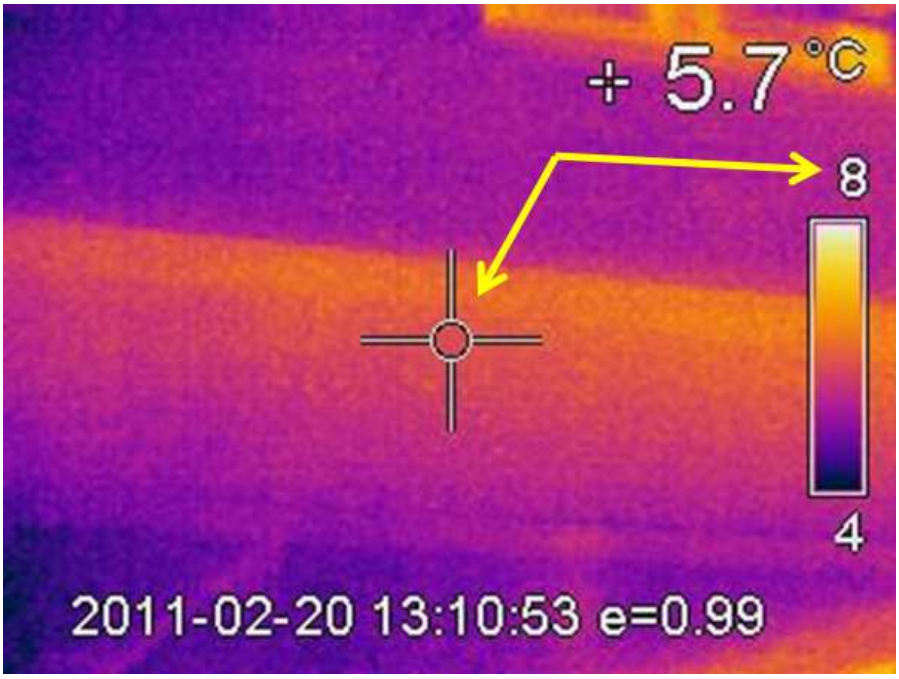
27 Example 1 of construction design /build defect

In the following photos (24-31) examples of new construction which failed to comply with its design objectives of a green and environmentally friendly home.

24 This home on a flood plain was built on steel uninsulated stilts in direct contact with uninsulated flloor



25 Photo 25 is an IR of photo 24. Heat doesn't always rise and in this example we see heat moving downwards to soffit of garage due to poor insulation.



26 Poor insulation to garage soffit where steels are not insulated and become a heat sink

27 The temperature of the support steel 15c with lower attached steel at 0.2c acting as a heat sink

28 The loss of heat through wall and floor to the garage below (photo 25) caused the lower inside wall to reach Dew Point with both surface and intertsial mould growth

29 This window frame did not have a thermal break confirmed by continuity of conductivity. This caused DPC on the window frame and window reveal

30 Despite having tickle vents visible they were not installed properly as they did not penetrate the window

30 The kitchen vent didn't appear to control ventilation (see photo 31)

31 The louvre in photo 31 removed. The builder didn't drill through the the concrete and steel lintel and mould formed behind the plastic louvre

28 Thermal loss, gain and "Emissivity"[63]

Heat energy from the sun is a radiant heat in the Infra-Red spectrum, which is short wave radiation**.** This heat energy coming through the glass heats up the building fabric and furnishings, in addition to any internal heat sources such as the heating system. The heat radiated off the fabric and furnishings is long wave radiation. Uncontrolled heat loss or gain can affect living conditions and cooling-heating costs and also result in isolated dew point condensation issues. Glass is a particular issue and manufacturers have developed low emmisivity coatings to reduce these effects.The low e coating on the glass allows most of the visible light to pass through as well as the short wave heat energy, but blocks long wave energy from passing through. This ensures the heat from inside the building is reflected back into the room and so heat losses are significantly reduced.
Emissivity is the value given to materials based on the ratio of heat emitted compared to a perfect blackbody, on a scale from zero to one. A black body would have an emissivity of 1 and a perfect reflector would have a value of 0.
Warm surfaces are usually cooled directly by air, but they also cool themselves by emitting thermal radiation. This second cooling mechanism is important for simple glass windows, which have emissivity close to the maximum possible value of 1.0. "Low-E windows" with transparent low emissivity coatings emit less thermal radiation than ordinary windows. In winter, these coatings can halve the rate at which a window loses heat compared to an uncoated glass window

These coatings are invisible to the naked eye and must be fitted on the correct side of the apperture to ensure homogernous emissivity.
Installing window glass the wrong way round can result in localised thermal differences and cause window frames and surrounds to have differing dew point temperatures.

This effect can be significant when thermal breaks are not installed in frames and can result in mould and biological activity, often in cavities, frames and even glass

Unfortunately builders or glazers do not always install or fit the glass the right way around and the emissivity coating should be checked for location when window areas are of concern

32 The Bohle meter is typically used for detecting and determining the location of low-E coatings on single panes or double glazed units (4-10 mm glass thickness of individual panes). When checking double glazed units, measurements must be taken from both sides in order to determine the exact position of the coating.

29 Example 2 of construction design /build defect Example

Photos 23-34 show simple faults which can have long term effects and costs

33 The damp proof membrane (DPM) did not rise high enough and the walls were saturated from penetrating and risng damp

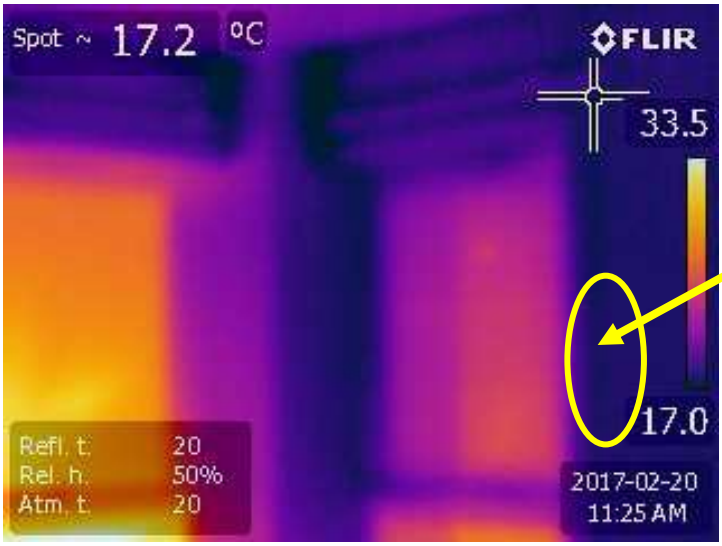
34 Pretty design of downpie hidden in canopy support but not adequate for downpour when outlet misses French Drain and penetrates the building

33 Infra-red survey

Infra –Red technology has brought massive benefits to the professional surveyor and especially the IEP. While there are benefits there are also drawbacks too, especially when these technical tools are used without training. It is important to realise infra-red cameras require a degree of training and many false readings can result if the camera operator hasn't achieved at least a level 1 accreditation. An infra-red survey can identify areas of concern which moisture meters and other measuring techniques cannot.These areas are described as Delta T (difference in temperature) where temperature differentials in similar materials is markedly different, these areas should be investigated.

Temperatures in well insulated environment should be homogenous and the camera shot would show all the same colours and temperature throughout.
Of course it is impossible to have a totally homogenous insulation with the same temperature signature in a building. Ceilings, different walls and windows will all show different temperatures but the technician will identify Delta t on the same surfaces. This can be seen in the following IR photos where even small Delta t provides a focus of attention.

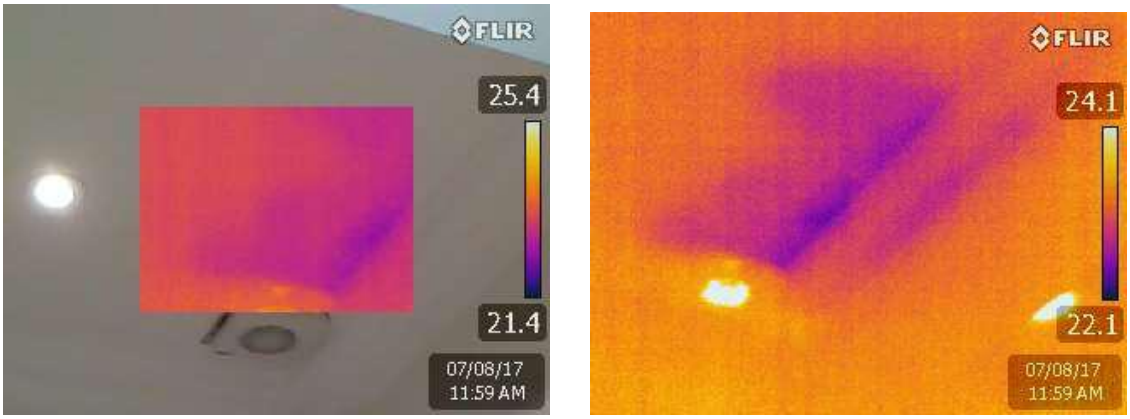
It should be understood that IR cannot identify moisture but wet surfaces are usually more heat conductive and therefore show up slightly cooler. Target areas must be assessed with moisture meters to confirm or deny moisture presence. Equally the IR camera can identify potential Dew Point Condensation risks and the IR camera when used in conjunction with the Psychrometric chart (Table 9) the measurement of surface temperatures can indicate potential risk of DPC.



Yellow circle showing 17c was opened up to expose mould growth caused by DPC. See below

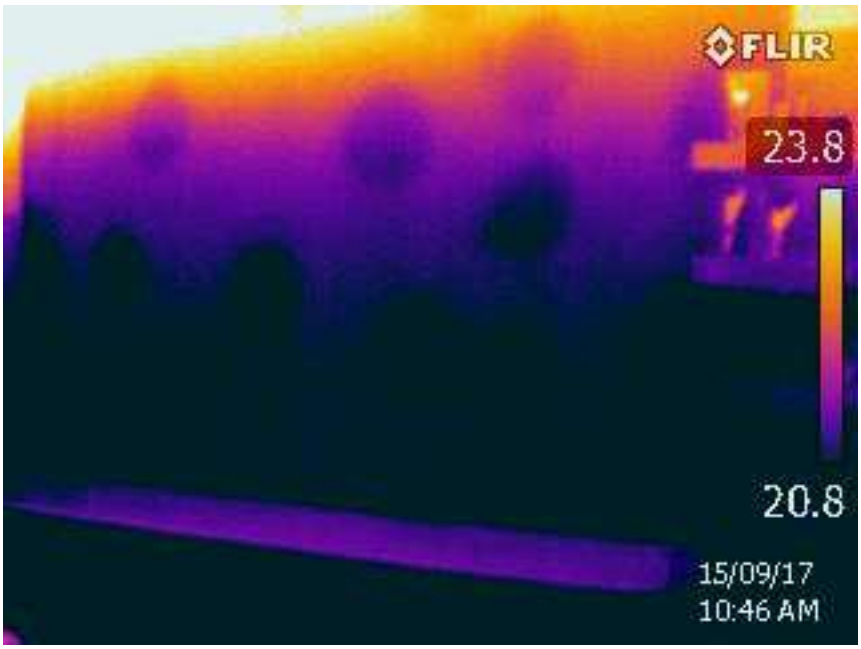
35 This IR photo shows temperature differences of 50% on same wall (17c and 33.5c) The relative humidity is only 50% and the wall is dry.

36 This photo is of the same was as photo 35 above but the yellow ring section removed to expose mould growth which was constanly infiltrating to affect occupants health

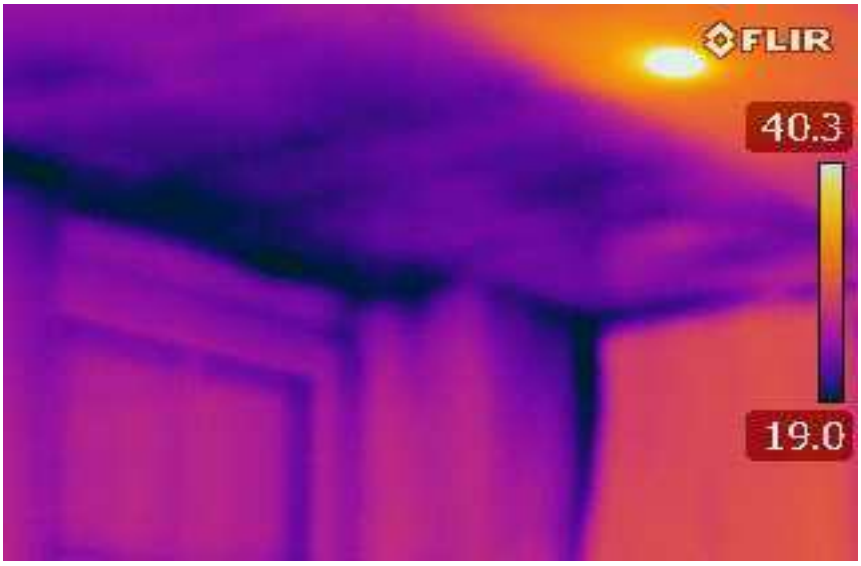


37 These pictures show a bathroom extract which was not connected to external ducting and IR shows possible damp areas confirmed by moisture measurement

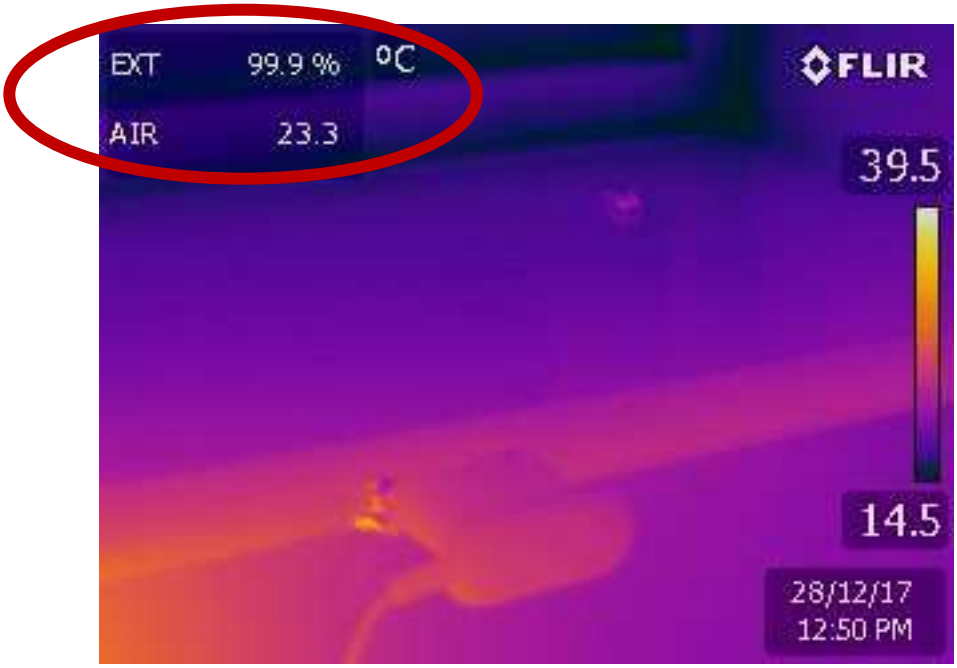
38 This house had cavity wall insulation poorly installed which caused internal condensation and mold growth



39 This is a construction defect where drywall (plasterboard) is affixed by Dot and Dab to an external brick wall and resulted in dew point condensation



40 Dew point condensation to a ceiling in a poolry insulated (cold) loft (mould growth above)



41 The IR camera recording 99.9% moisture content and air temperature allowing Dew point to be calculated

34 Influencing air sampling results

In this example (photo 42) builders removed the visible mould and believed the walls only required redecoration. Sampling the cavity showed low counts, obvioulsy obscured by debris see (Table 3) despite very low sampling time.

With gaps and air pathways from internal cavities to the occupied spaces a concern was that the occupants would be exposed to contamination ingress for years to come.
Photo 44 shows a Minnesota blower door which placed the building under negative pressure and make up air would flow through available air pathways including cavity walls.
It can be seen in Table 22 that the areas tested was contaminated from mould growth due to the poor construction practice. This was not present prior to negative pressure application. Basically a drip feed of contaminates for occupants in the completed house if not challenged.

42 New construction where builders removed surface mould and stated only redecoration was necessary

43 Negative Pressure blower door fitted to front door and produces negative pressure to property therby exposing leaks

SPORE TRAP REPORT: NON-VIABLE METHODOLOGY

Location:	5: Sample Point 5				6: Sample Point 6				7: Sample Point 7				8: Sample Point 8			
Comments (see below)	None				None				None				None			
Lab ID-Version‡:	7100042-1				7100043-1				7100044-1				7100045-1			
Analysis Date:	05/02/2016				05/02/2016				05/02/2016				05/03/2016			
Sample volume (liters)	30				30				30				30			
Background debris (1-4+)††	4+				4+				4+				>4+			
	Count	Count/m3	DL/m3*	%	Count	Count/m3	DL/m3*	%	Count	Count/m3	DL/m3*	%	Count	Count/m3	DL/m3*	%
Hyphal fragments	1	33	33	n/a									3	100	33	n/a
Pollen	2	67	33	n/a	1	33	33	n/a								
§ TOTAL FUNGAL SPORES	85	2,800	n/a	100	25	3,200	n/a	100	6	200	n/a	100	148	19,000	n/a	100
Ascospores																
Basidiospores																
Chaetomium																
Cladosporium	1	33	33	1												
Nigrospora	1	33	33	1												
Other brown													2	67	33	<1
Penicillium/Aspergillus types	83	2,800	33	98	24	3,200	130	99	6	200	33	100	140	19,000	130	99
Scopulariopsis													6	200	33	1
Smuts, Periconia, Myxomycetes					1	33	33	1								
Stachybotrys																
Torula																
Ulocladium																

Table 22 Lab analysis of air samples following application of negative pressure. Very dirty (4+) but highly contaminated air sample

35 The importance of air pathways

The World Health Organisation (WHO) has stated that inhalation of mold spores and particularly fragments may have a risk factor 40 times higher than ingestion. This of course includes all potential forms of contaminates.[37] The significance of this can be explained because small particles <7.5 micron can bypass human defence systems and enter the blood stream through the lower respiratory system. These small particles must be assumed to be either allergenic or potentially toxic with potential for inflammatory response. With the recognition of this major factor, it is of course important to identify contamination sources and their potential route (air pathway) which may spread contaminates far from their origination.

The IEH will use special equipment and knowledge of air flow to identify these important risks.

44 Typical equipment carried by the IEHP

45 The Foxboro Mirran used to identify Volatile Organic Compounds (VOCs) and used in conjunction with trace gas SF6 to monitor air pathways

46 A smoke generator used to identify air pressure differentials and air pathways

47 Monitoring dust (including mold fragments) post decontamination to assess efficacy of air cleaning

36 Is the property Safe?

Whether or not the building is safe are the most common questions after any form of investigation is undertaken. There are many International guidelines [64] on exposure but no standards which can dictate health or safety and there are no maximum levels of exposure. Some will quote a maximum of 500 Colony Forming Units (CFUs) while others 350 CFUs.of the same species[73] The symbiotic effects of different biological agents, chemicals and human genetic differences or susceptibility means maximum exposure levels are unlikely in the near future. Investigators can never definitively conclude or prove that an environment is safe and presents no risk of exposure to biological agents.[67] In part; this means that if investigators have not looked or tested for biological agent, they cannot say it's not there. [68]

"Absence of evidence is not evidence of absence".

Sometimes medical examination is required to confirm the presence of building contaminates in blood or urine.

Some rely on ERMI score while others total spores counts, and mycotoxin analysis, CFUs, VOCs and bacteria too, but the reality is no single score system can accommodate all possible contaminates either singly or symbiotically.

An exception is the HERTSMI2 [23] which clearly states the limitations and of course the specific risk and hazard and has supportive evidence. Of course even here we have the limitations of CIRS specific risk.

The risk and hazard assessment will be a culmination of all available information coupled to occupant's reaction and medical symptoms. Unfortunately the only real measurement is exposure and some homes may not be decontaminated successfully. [65] Considering all the possible contaminates which may be present the cost and time required to explore all possible health hazards would be prohibitive for most. An important issue is that there are no maximum exposure levels for most of the likely contaminates and symbiotic action could multiply any effects between differing contaminates. The most important aspect is the occupant's personal genetics and immune response and this is perhaps the most important variable. In essence this may mean what is safe for some may be harmful to others.[13-14]

37 Example 3 Risk assessments

The following examples explain some of the vagaries in risk and hazard assessment.

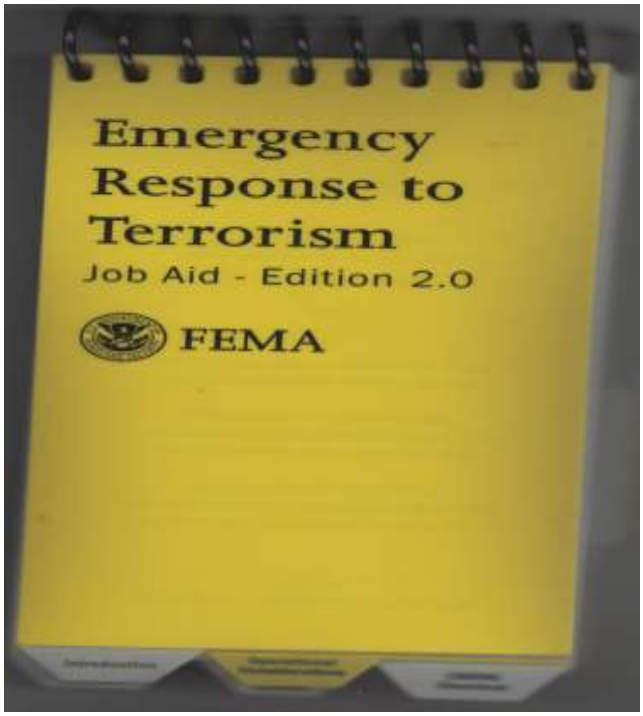
Table 23

Risk factors	Rating	Issues
Age of occupants over 65 or under 5	10	Reduced or developing immune system
Immune response issues Chemo/radiotherapy etc	10	Reduced immune system
Atopic or sensitised individuals	10	Genetically prone HLA gene etc
New or emerging symptoms	10	Building related issues
Contamination issues proven	5	Risk assessment
Potentially toxic contamination found	10	Higher risk
Historic issues and basis of concern	5	Risk multiplier and confirmation
Acute exposure	5	Short term issues only
Chronic (long term exposure)	10	Dose issues
Long term damp or water damage	10	Reflects risk when not properly repaired
*Occupants with open wounds/surgery etc *	15	Infection issues
	Score total	

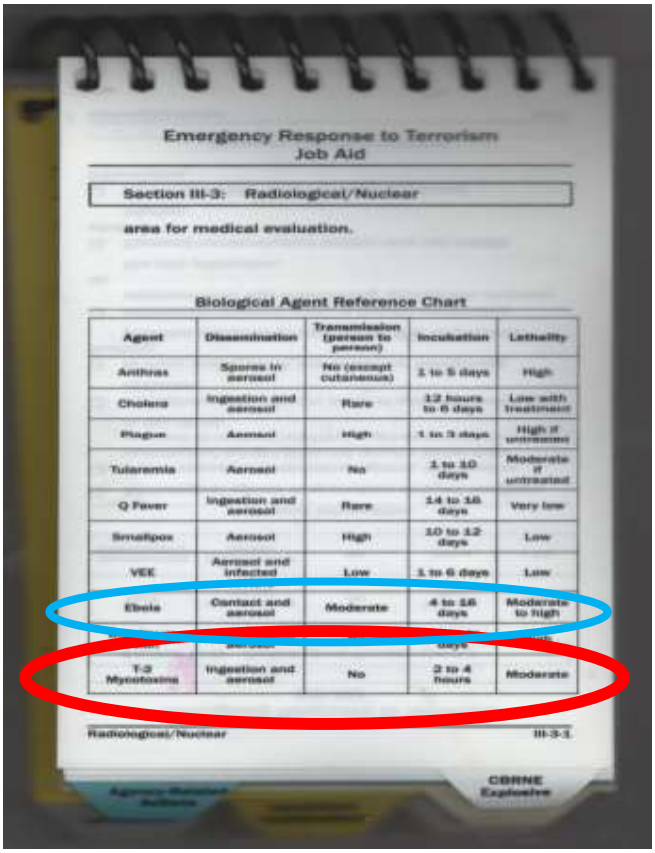
Note. The above score card (Table23) was a developed by the author but has absolutely no scientific or medical value and is for risk assessment purposes of the client only. Scores over 30 are cause for concern although even low scores may represent a health hazard to some sensitised occupants. There are no recognised safe levels of exposure and ambient levels are used for comparison

48 The tenants of this ground floor flat were extraordinarily happy and healthy. The local government landlord asked me to investigate. An underground leak resulted in all plasterboard (drywall) being wet to a height of 1 meter (rising damp) The mould was even worse in the cavities but the species wasn't affecting health indeed the family actually stated they felt better since the mould developed?

49 This minor leak from an en suite shower tray resulted in mould growth in this 5 month old new build. Analysis proved T2 toxin from Trichoderma growing under the carpet. **(**see photo 50-51) and within 4 weeks of moving out all symptoms disappeared.



50 The FEMA handbook for response technicians which lists Mould T2 toxin as a WMD



Emergency Response to Terrorism
Job Aid

Section III-3: Radiological/Nuclear

area for medical evaluation.

Biological Agent Reference Chart

Agent	Dissemination	Transmission (person to person)	Incubation	Lethality
Anthrax	Spores in aerosol	No (except cutaneous)	1 to 5 days	High
Cholera	Ingestion and aerosol	Rare	12 hours to 6 days	Low with treatment
Plague	Aerosol	High	1 to 3 days	High if untreated
Tularemia	Aerosol	No	1 to 10 days	Moderate if untreated
Q Fever	Ingestion and aerosol	Rare	14 to 16 days	Very low
Smallpox	Aerosol	High	10 to 12 days	Low
VEE	Aerosol and infected	Low	1 to 6 days	Low
Ebola	Contact and aerosol	Moderate	4 to 16 days	Moderate to high
T-2 Mycotoxins	Ingestion and aerosol	No	2 to 4 hours	Moderate

Radiological/Nuclear III-3-1

CBRNE Explosive

Page 111-3-1 FEMA Emergency Response to terrorism. Feb 2003

Blue Ebola Lethality Moderate to high
Red T2 Mycotoxin Lethality Moderate

Note The author presented a desk top exercise to UK government and simulated terrorist attack using T2 toxin (2014) produced by Trichoderma mold.

51 USA government agency **"**FEMA" recognise T2 Mycotoxin as a possible terrorist Weapon of Mass Destruction with lethality as "Moderate" See also Ebola lethality (Moderate to high)

38 Conclusion

The assessment of building related illness is very complex and requires competent professionals with experience, recognised training and certification coupled to the use of specialist equipment and recognised laboratory analysis. The qualifications may take years to achieve and the Indoor Environmental Professional (IEP) will have a broad knowledge of building construction, health issues and symptoms and all aspects of contamination and of course decontamination.

The ACGIH [3] section 2.1.4 state the possession of a degree does not automatically qualify a person as an expert. Equally the lack of a degree does not mean a person is unqualified, however they should be qualified and have obtained the necessary certifications and registrations. While the forgoing sections have highlighted typical failures and flaws in testing and investigation, it should be remembered that all investigation and sampling techniques have both strengths and weaknesses and the IEP will adapt and account for these issues to provide a meaningful report.The recipient of the flawed investigation and mould report may be under a false impression of safety or risk and we hope this paper will assist those making choices regarding investigation.

The IEP may cost a little more than other surveyors but the unfortunate reality is that without understanding the risk and hazard properly, health improvement even with treatment, is likely to be impossible if hazardous

exposure is always present. IEPs may admit that investigating a sick building for building related illness is more of an art than a science and this is because of so many variables. These variables are complex and although accuracy and even precision can be improved it will be through increased sampling, types of sampling and cost. The IEP will balance the symptoms and doctors/client likely requirements against budget and practicalities.

39 How to identify a professional and competent IEP

a. In all cases a broad based knowledge of building construction, water damage, mould and Indoor Air Quality is required coupled to training and certification. The understanding of contamination and decontamination coupled to vector agents is a must. A minimal understanding of health impact and ability to develop sampling and investigation hypothesis identifying benefits and shortfalls with a clear understanding of health and safety and relevant legal compliance

b. In the USA some states have certification requirements while others rely on industry certification bodies such as CIEC or CIH and guidance bodies such as ACGIH.

c. In the UK the main certification bodies are CIEH and BOHS but both focus on occupational health therefore the onus is on the IEP to prove they are competent with broad based training and internationally recognised certification bodies such as ISO and this may follow CIEC and of course USA certification where none apply in UK

d. Importantly the leading body international body ACGIH states the possession of a degree or PhD is by no means identification of competence and an engineering background with relevant training and certification may be more relevant.

e. In the UK it is apparently a criminal offence under the Fraud Act 2006 and Unfair Trading Regulations 2008 to promote oneself as a qualified IEP when recognised accreditation and competence has not been achieved or most importantly proven.(This is not legal advice)

Acronym

ACGIH	American Congress of Governmental Hygienists
AIHA	American Industrial Hygiene Association
ATP	Adenosine Tri Phosphate
aW	Water Activity
BRI	Building Related Illness
CFM	Cubic Feet per Minute
CFUs	Colony Forming Units
CIRS	Chronic Inflammatory Response Syndrome
DAMPS	Danger associated molecular patterns
Dot & Dab	Random blobs of plaster used to hold drywall to concrete and brick walls
DPC	Dew Point Condensation

DPM	Damp Proof Membrane
DQOs	Data Quality Objectives
DIY	Do It Yourself
EMC	Equivalent Moisture Content
EMR	Electro Magnetic Radiation
EPA	Environmental Protection Agency (USA)
ERH	Equilibrium Relative Humidity
ERMI	Environmental Relative Mold Index
EXT	External
GAO	Government Accountability Office (USA)
Grains	The USA equivalent of g/kg in Grains per pound
g/kg	Grams of moisture per kilogram of dry air
HEPA	High Extraction Particulate Arrest
HERTSMI	Health Effects Roster of Type Specific Formers of Mycotoxins & Inflammagens
HLA	A specific genetic difference which may affect 25% of the population
HSE	Health and Safety Executive (UK government body)
IEH	Indoor Environmental Hygienist
IEP	Indoor Environmental Professional
IICRC S520	Institute Inspection Cleaning Restoration Contractors Mold guidelines
Instatscope	Portable machine for assessing airborne mould and associated contaminates
IR	Infra-Red Thermography
ISO	International Standards Organisation
MC	Moisture Content
µ Micron	One millionth of a metre or micron
Mycometer	Fluorogenic detection of enzymes associated with all mould
NPU	Negative Pressure Unit
NYCG	New York City Guidelines
PAMPS	pathogen associated molecular patterns
QPCR	Quantitative Polymerised Chain Reaction
R value	Thermal resistance value of a material
RH	Relative Humidity
RLU	Relative Light Units
RMI	Relative Mold Index (see ERMI)
RR988	HSE paper on stratification of particulates
SAS	Surface Air Sampling
SBS	Sick Building Syndrome
SF6	Sulphur Hexafluoride 6 (trace gas)
sp	Species
U value	The value of heat transfer or transmittance in any material
UK	United Kingdom
USA	United States of America
VCT	Visual Contrast Test which may assist in the identification of brain inflammation
VOCs	Volatile Organic Compounds
WHO	World Health Organisation
WHO 2009	Indoor Air Quality Dampness and Mould 2009
WDB	Water Damaged Building
WME	Wood Moisture Equivelant

Bibliography

1	Flannigan- Samson- Miller Microorganisms in Home and Indoor Work Environments,
2	Occupational Medicine Effects of the Indoor Environment on Health James Selzer MD
3	ACGIH Bio aerosols Assessment and Control
4	New York City Guidelines https://www1.nyc.gov/assets/doh/downloads/pdf/epi/epi-mold-guidelines.pdf
5	NIOSH ALERT https://stacks.cdc.gov/view/cdc/12128
6	CIRS Review of HERTSMI and ERMI https://www.isiaq.org/docs/Papers/Paper658.pdf
7	(GAO, AIHA Recognition, Evaluation, and Control of Indoor Mold, CDC/Rao 3/07),
8	Consensus document https://www.survivingmold.com/docs/CONSENSUS_FINAL_IEP_SM_07_13_16.pdf
9	U.S. EPA, A Brief Guide to Mold, Moisture, and Your Home; EPA 402-K-02-0003, U.S. Environmental Protection Agency, Office of Air and Radiation Indoor Environments Division, 2002. http://www.epa.gov/mold/pdfs/moldguide.pdf
10	World Health Organization, WHO Guidelines for Indoor Air Quality: Dampness and Mould, 2009. http://www.euro.who.int/__data/assets/pdf_file/0017/43325/E92645.pdf
11	Policyholders of America CIRS review http://www.survivingmold.com/docs/POA_MOLD_7_27_10_final.pdf
12	Consensus Document Surviving Mold https://www.survivingmold.com/docs/CONSENSUS_FINAL_IEP_SM_07_13_16.pdf
13	Biotoxin Illness http://www.survivingmold.com/diagnosis
14	CIRS Symptoms http://www.survivingmold.com/mold-symptoms
15	VCS test http://www.survivingmold.com/store1/online-screening-test
16	Free and bound water AIHA Recognition Evaluation and Control of Indoor Mold ISBN 978-1931504-92-8
17	Humidity Requirements for mold growth http://pubmedcentralcanada.ca/pmcc/articles/PMC1056928/pdf/applmicro00290-0019.pdf
18	AIHA Field Guide for determination of biological contaminates in Environmental Samples sec 3.4.1 2nd Edition Stock No IMOF 05-678
19	IICRC S500 Third edition
20	Lab test http://www.survivingmold.com/diagnosis/lab-tests
21	ERMI research paper https://www.epa.gov/sites/production/files/2016-01/documents/moldiness_index_1.pdf
22	ERMI diagnosis http://www.survivingmold.com/diagnosis/hertsmi-2
23	ERMI and HERTSMI 2 used as a tool https://www.isiaq.org/docs/Papers/Paper658.pdf
24	Registered Surveyor http://www.rics.org/uk/knowledge/glossary/building-surveying/

25	Mould sampling British Standards Institute BS 12999 16-19 and IICRC S520
26	Environmental Survey Carbon monoxide https://www.osha.gov/dts/sltc/methods/inorganic/id209/id209.html
27	Environmental Survey Carbon di32-34-oxide https://www.osha.gov/dts/chemicalsampling/data/CH_225400.html
28	UK Ventilation rates https://www.gov.uk/government/publications/ventilation-approved-document-f
29	USA ventilation rates https://www.nrel.gov/docs/fy14osti/61128.pdf
30	Photo Ionisation Detector http://www.raesystems.com/sites/default/files/content/resources/pid_handbook_1002-02.pdf
31	Galileo https://sciencealert.com/watch-a-bowling-ball-and-feather-fall-in-world-s-biggest-vacuum-chamber
32	Stokes Law Encyclopaedia Britannica https://www.britannica.com/science/Stokess-law
33	Stokes Law paper http://nvlpubs.nist.gov/nistpubs/jres/68b/jresv68bn4p143_a1b.pdf
34	Particle drop Guttation droplets of Penicillium nordicum and Penicillium verrucosum contain high concentrations of the mycotoxins ochratoxin A and B Manfred Gareis Æ Eva-Maria Gareis
35	Particle Drop Fungal Fragment35s as36dddd38 Indoor Air Biocontaminants Rafał L. Go´rny,1† Tiina Reponen,1* Klaus Willeke,1 Detlef Schmechel,2 Enric Robine,3 Marjorie Boissier,3 and Sergey A. Grinshpun1
36	Particle Drop Detection of Airborne Stachybotrys chartarum Macrocyclic Trichothecene Mycotoxins on Particulates Smaller than Conidia T. L. Brasel, D. R. Douglas, S. C. Wilson, and D. C. Straus* Department of Microbiology and Immunology, Texas Tech University Health Sciences Center, Lubbock, Texas Received 22 March 2004/Accepted 16 August 2004
37	WHO Bulletin 77 1999 page 754 Mycotoxins in humans http://www.who.int/bulletin/archives/77(9)754.pdf?ua=1
38	Air flow by NPU https://www.youtube.com/watch?v=4IP4dXk2BVY
39	Health and Safety Executive paper on particle capture http://www.hse.gov.uk/research/rrhtm/rr988.htm
40	Quality Assurance Project Plan for Verification of Mycometer®-test Rapid Fungi Detection and BactiQuant®-test Rapid Bacteria Detection Technologies, Battelle, Version 1.0, April 5, 2011.
41	Quality Management Plan for the ETV Advanced Monitoring Systems Center, Version 8. U.S. Environmental Technology Verification Program, Battelle, April 2011.
42	Group 1 and 2 moulds Group 1 water damage indicators and often pathogenic. Group 2 are normal environmental mold found in ambient air See ERMI QPCR also Table 10 and 11 http://www.survivingmoldillness.com/ermi/
43	EPA Schools and Commercial buildings

	https://www.epa.gov/mold/mold-remediation-schools-and-commercial-buildings-guide
44	British Standards on mould sampling BS16000 16-19
45	HSE Approved List of Biological Agents. Includes (aspergillus *fumigatus)* http://www.hse.gov.uk/pubns/misc208.pdf
46	Journal of Occupational Environmental Hygiene, ERMI health assessment by EPA Rosenbaum PF, Crawford JA, Hunt A, Vesper SJ, Environmental Relative Moldiness Index and Associations with Home Characteristics and Infant Wheeze. Journal of Occupational and Environmental Hygiene, 12: 29–36 ISSN: 1545-9624 print / 1545-9632 online Copyright 2015 JOEH, LLC DOI: 10.1080/15459624.2014.933958 http://www.tandfonline.com/doi/abs/10.1080/15459624.2014.933958
47	ERMI Environmental Relative Mold Index https://www.epa.gov/sites/production/files/2017-04/documents/ermi_fact_sheet.pdf
48	ERMI Not validated https://www.epa.gov/sites/production/files/2015-09/documents/20130822-13-p-0356_glance.pdf
49	ERMI predictor of Health impact https://www.epa.gov/sites/production/files/2017-04/documents/epa_research_methods_for_studying_mold_fact_sheet.pdf
50	Data Quality Objectives EPA https://www.epa.gov/sites/production/files/documents/guidance_systematic_planning_dqo_process.pdf
51	ATP https://biologydictionary.net/atp/
52	Temperature growth of mold ACGIH section 19.5.1.1 ISBN 882417-29-1
53	Temperature and growth conditions for mold Flannigan-Samson-Miller Microorganisms in Home and Indoor Work Environments second edition
54	Leadership in Restorative Drying Ken Larson (2014 Gold Edition)
55	British Standards on restoration BS12999 (PAS 64)
56	Joe Lstiburck /John Carmody Moisture Control Handbook. Principles and practices for residential and small commercial buildings
57	Dr. Paul Baker (Glasgow Caledonian University) January 2011 U-values and traditional buildings *In situ* measurements and their comparisons to calculated values Technical Paper10
58	Defects and Deterioration in Buildings 2nd Edition Barry A. Richardson
59	Defects in Buildings Property Services Agency (PSA) Department of environment Her Majesty's Stationary Office
60	Understanding Housing Defects Duncan Marshall -Derek Worthing- Roger Heath
61	Understanding Housing Defects Duncan Marshall -Derek Worthing- Roger Heath Second Edition
62	Surveying Buildings Malcolm Hollis Fifth Edition (RICS)
63	The Low-E Window R&D Success Story". Windows and Building Envelope Research and Development: Roadmap for Emerging Technologies (PDF). U.S. Department of Energy. February 2014. p. 5.
64	Bob Brandy World Wide Exposures Standards for Mold and Bacteria
65	Institute of Medicine 2004 page 242 (Move out)
66	Flannigan-Samson-Miller Microorganisms in Home and Indoor Work Environments second edition page 144

67	National Health Service (UK) https://www.nhs.uk/chq/Pages/How-do-I-get-rid-of-damp-and-mould.aspx
68	Sick Building Syndrome Advances in Applied Microbiology Vol 55 Edited David C. Straus
69	Burge *et al* 1999
70	Christensen 1950
71	Lyon et al. 1984
72	Robert Brandys PhD. In field test methods and reference standards for portable High Efficiency Air Filtration Equipment (HEPA)
73	Worldwide exposure standards for mold and bacteria Robert Brandy PhD 8th Edition
74	Post Remediation testing and verification 2011 Robert Brandy PhD 4th edition
75	CR-WLS-CMH-AMRT Certifications achieved in USA but annual subscriptions not continued