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

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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 and hazard 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 often 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 or 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]

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. More importantly the computer program assesses average counts and not specific hazardous (group 1) moulds which are generally accepted as being the toxic species.[42]

The typical failure issue 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]
The scope can sometimes identify "Hot" areas as red, but the green or amber reading is meaningless.

5 The Instacope and Mouldscope can provide a risk assessment but rarely provide a hazard assessment

Fig 1 Showing typical Bell chart distribution but missing peripheral counts

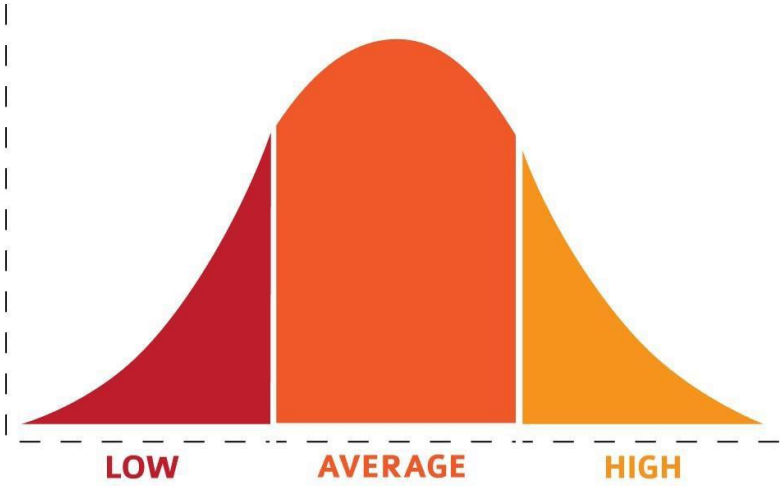


Fig 1 *The Instascope records only average counts and ignores the most important and usually lower counts of toxic moulds found in properties, where even single figures can be major indicators of health hazards*

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]

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 from a swab 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 providing Colony Forming Units (CFUs)

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 in terms of health risk.

An increase in the number of samples taken can improve accuracy but when no maximum exposure levels exist even accurate counts can be meaningless in isolation.

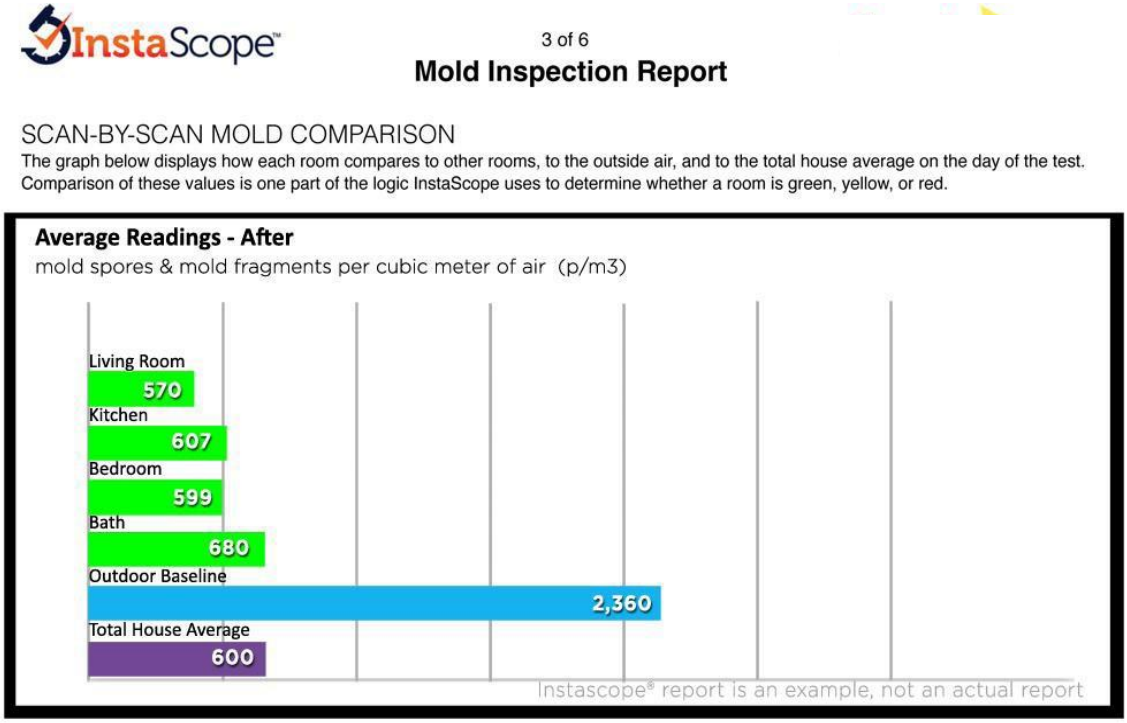


Table 5 Worthless information in terms of risk or hazard identification of mould

Mycometer®-air

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

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

Unfortunately despite being a good tool usually used for wrong purposes

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 and worthless risk or hazard assessment

10. Recognising the shortfalls of Air and surface sampling with culture-based methods

The mould surveyor may use culture plates in either an air sampling vacuum pump (Anderson 6) 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 house 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 possible 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

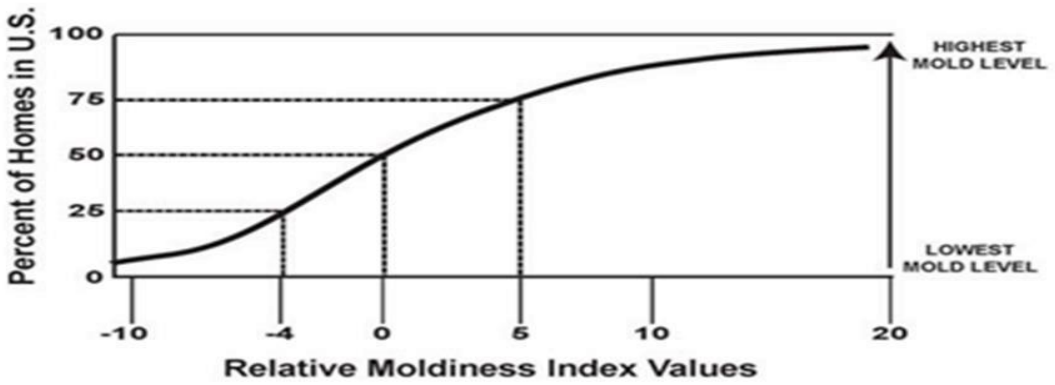


Table 9 Showing the Mold Index against 1026 properties in USA

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” but chronic 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.

Building Forensics
BUILDING RELATED ILLNESS

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	79	16
Aspergillus restrictus	290	59
Aspergillus sclerotiorum	10	2
Aspergillus sydowii	230	48
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
Paecilomyces variotii	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
Mucor/Rhizopus	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**

Building Forensics
BUILDING RELATED ILLNESS

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	9	2
Aspergillus niger	2	1
Aspergillus ochraceus	ND	<1
Aspergillus penicillioides	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
Paecilomyces variotii	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
Mucor/Rhizopus	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 these 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. The two leading issues in successful investigation are budget and IEP competence.

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 soft friable cotton swabs on hard 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 but not clearance.

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.

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

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 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

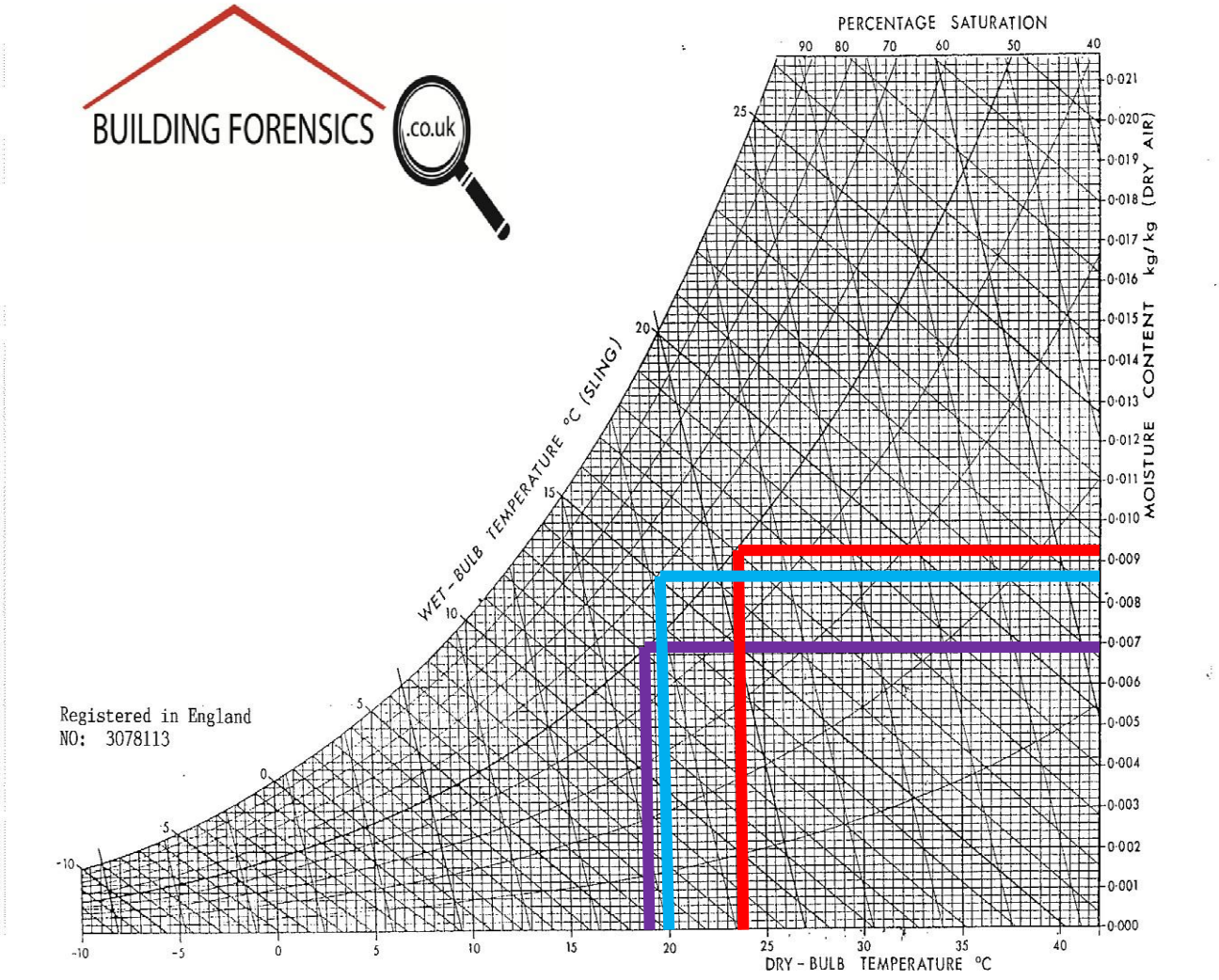
In Table 14 below we see that Rh is a worthless measurement without temperature and more importantly the calculation of air moisture , (known as specific humidity) as calculated on the “Psychrometric chart” It can be seen the higher the temperature the more moisture air can hold, but equally the lower 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 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

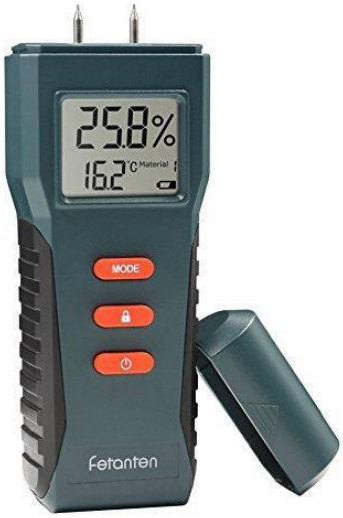
See photo 10 20c @60% Rh 0087g/kg of moisture per kg of dry air (measured in grains per pound in USA)

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



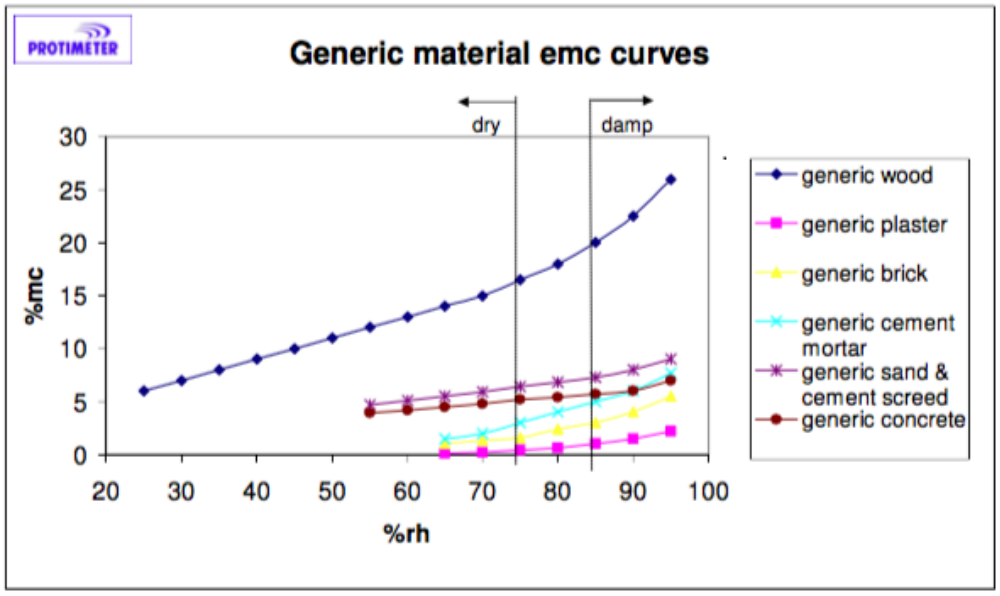
12 The conductive moisture meter is configured to calculate moisture content of wood only. Table 15 next provides a very rough comparison for other materials.

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)

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



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
Note EMC is also referred to as a state where a material is neither gaining or loosing moisture

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. 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 a 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 temperatures but different response to dew point condensatio

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 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

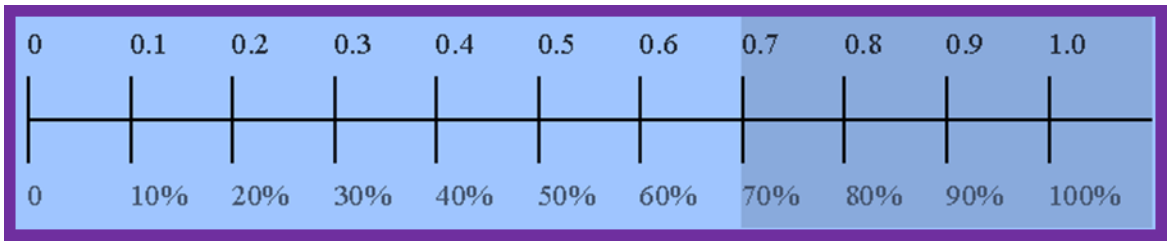


Table 18 **The correlation between RH and a_w**

24. The following table shows water requirements for active mould growth [5368]
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 aw 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 aw 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

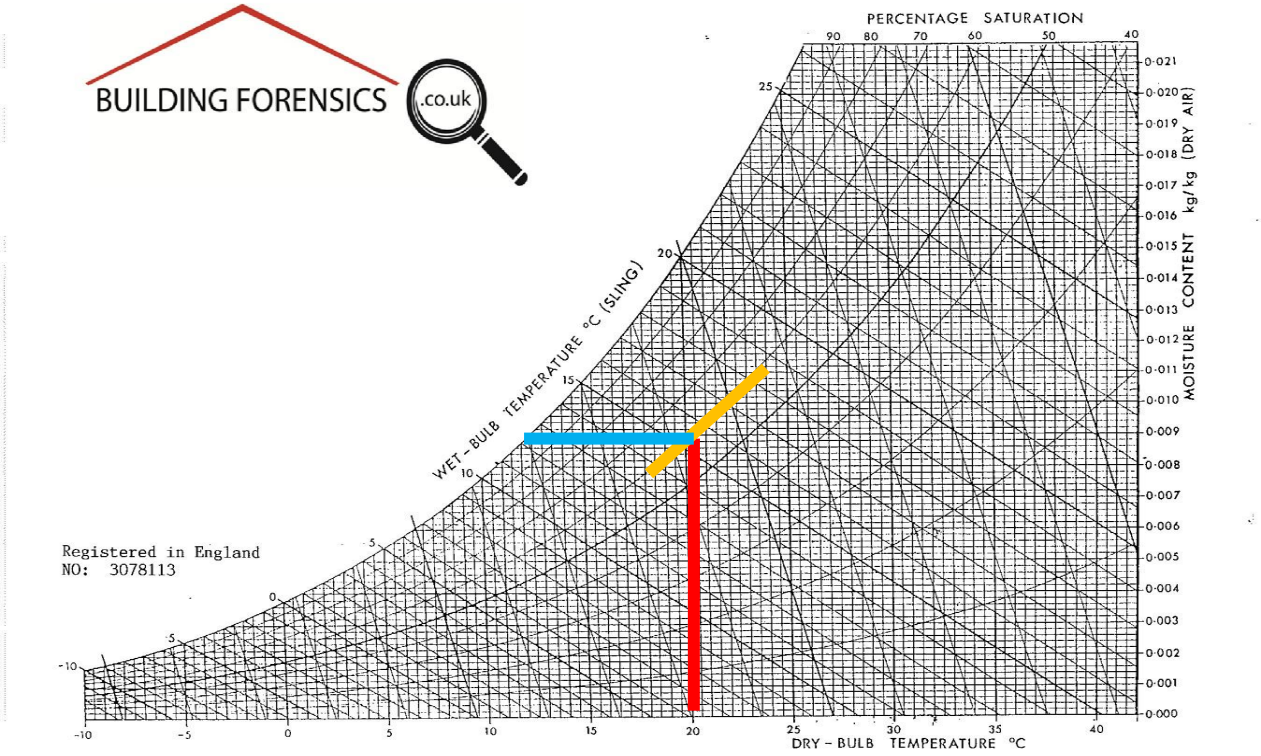


Table 21

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:

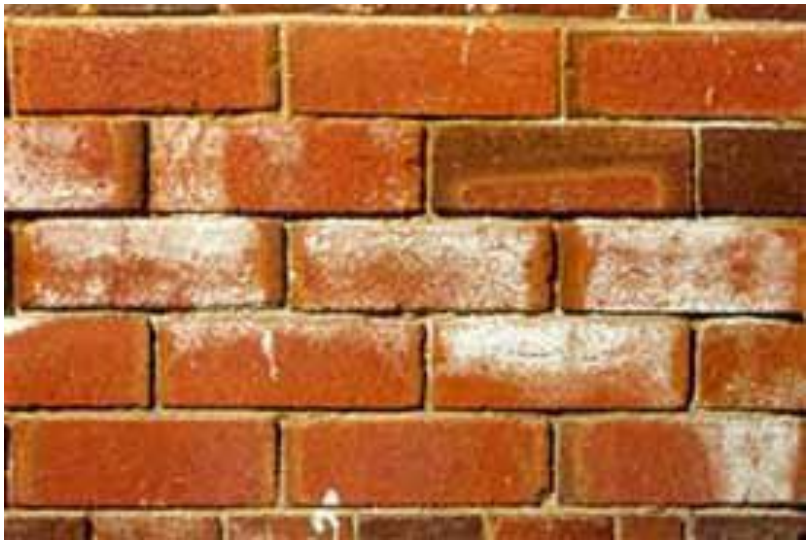
- Carbon rich materials can influence conductive and radio meters providing false results
- Lead paint on dry wood surfaces will show wet.
- Hygroscopic salts adsorb moisture from the air and can cause false wet readings on dry walls
- Hygroscopic salts such as Nitrates and chlorides from ground water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

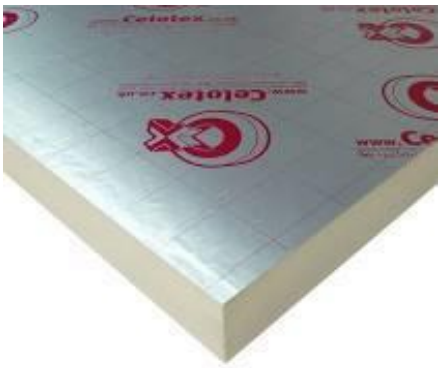
Some building materials have a high carbon content which causes high conductivity and false wet readings on conductive moisture meters

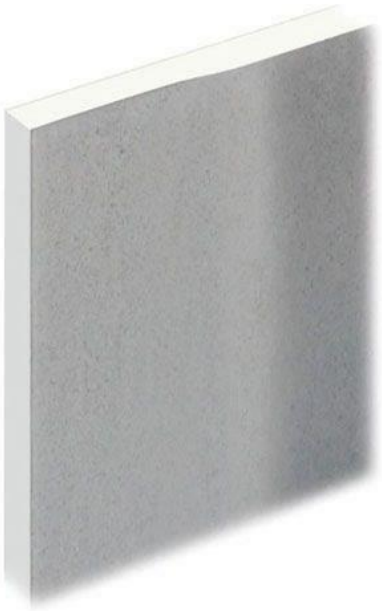
17 Cinder block with high conductivity due to high carbon content

18 Chloride and nitrate salts of sodium give false wet readings



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





20 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.

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

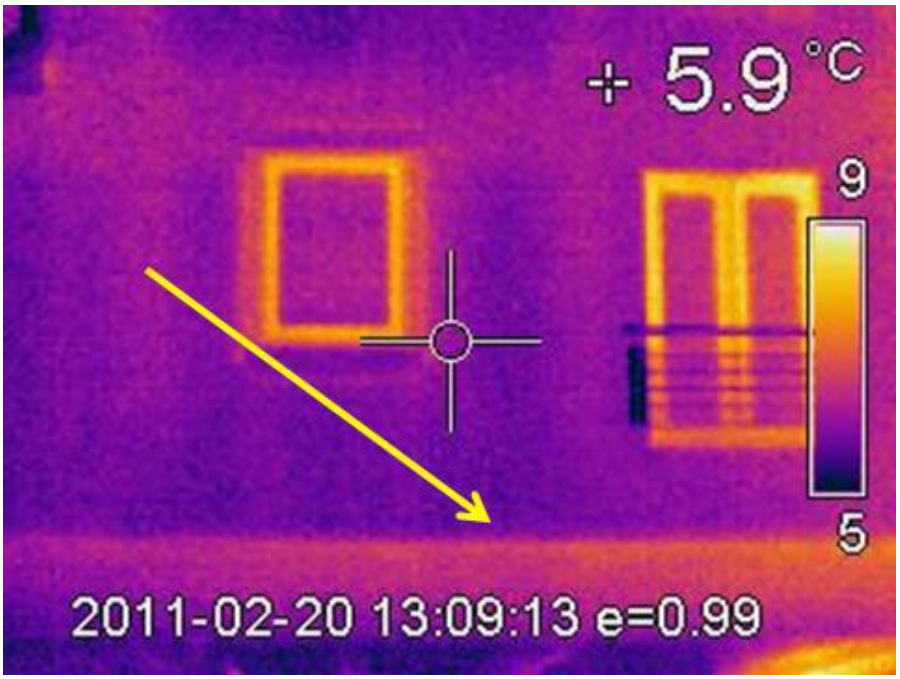
22 The rear of the bedside cabinet against a cold external wall resulting in DPC

23 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 during the inspection

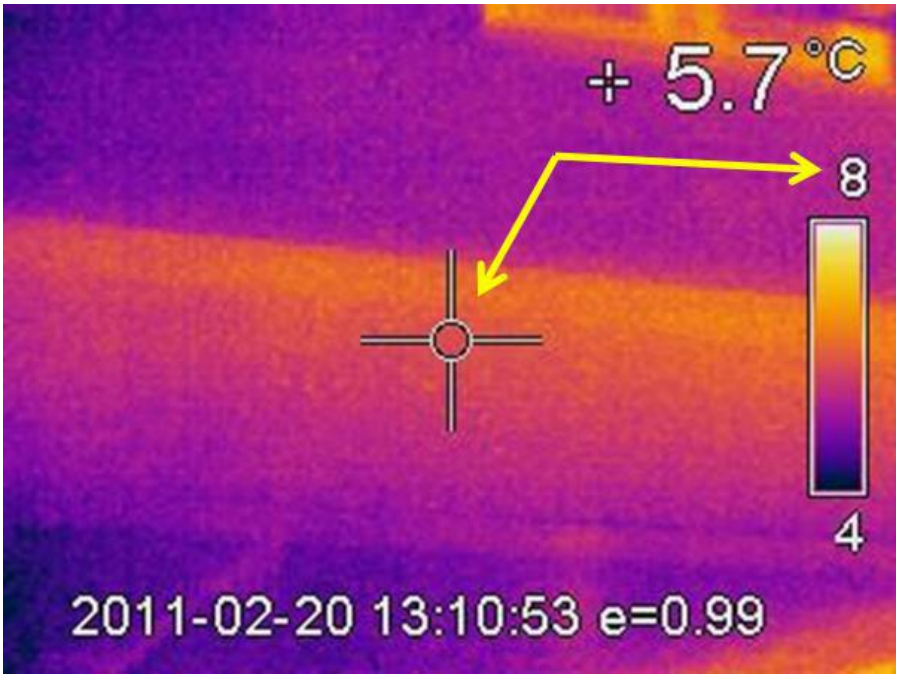
27 Example 1 of construction design /build defect

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 floor



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 frame to outside

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

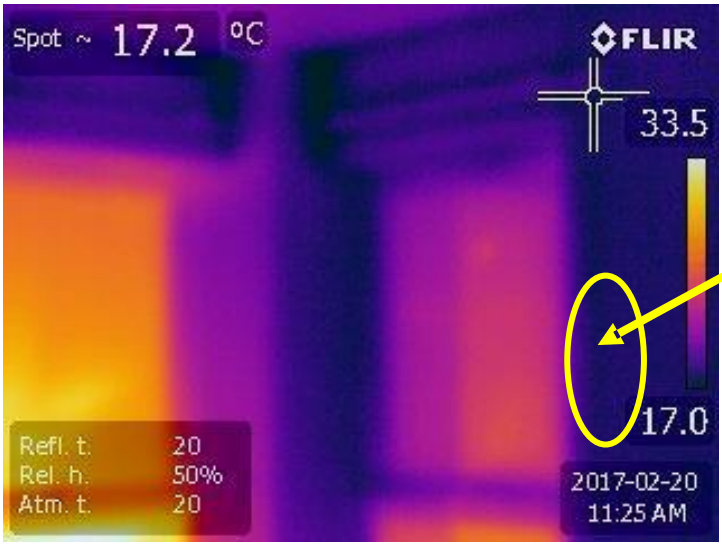
31 The louvre in photo 31 removed. The builder didn't drill through the the concrete and steel lintel and mould formed behind the plastic louvre

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.

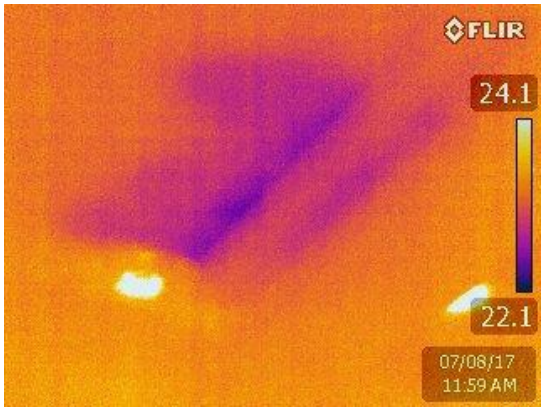
It should be understood that IR cannot identify moisture but wet surfaces are usually more heat conductive and therefore show up slightly cooler. Target areas must be assessed with moisture meters to confirm or deny moisture presence. Equally the IR camera can identify potential Dew Point Condensation 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

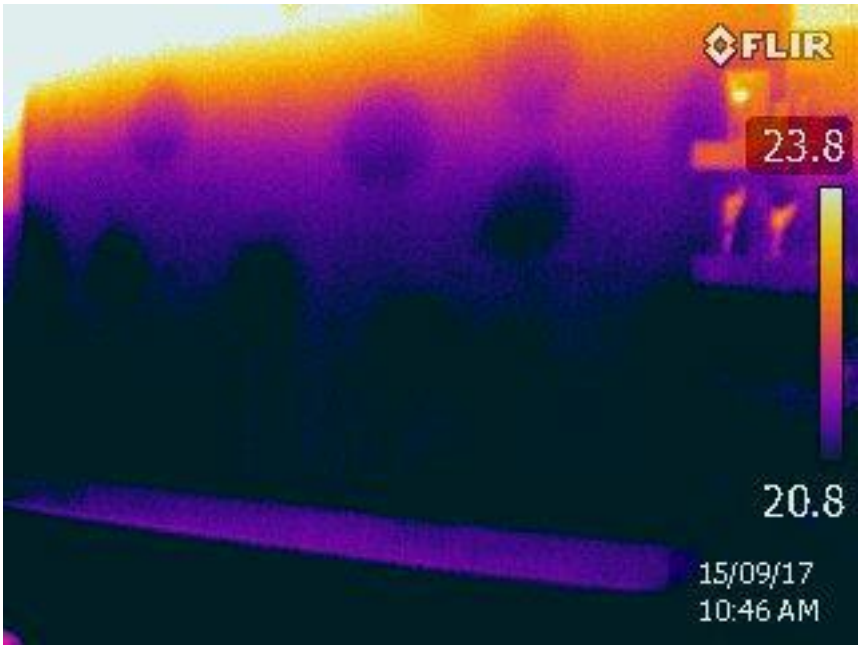
35 This IR photo shows temperature differences of 50% on same wall (17c and 33.5c) The relative humidity is only 50% and the wall is dry.

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

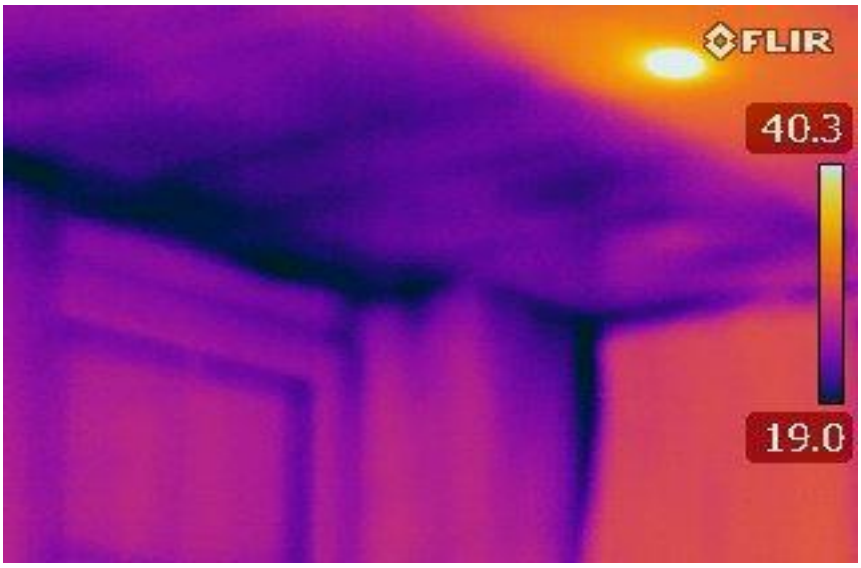


37 These pictures show a bathroom extract which was not connected to external ducting and IR shows possible damp areas confirmed by moisture measurement

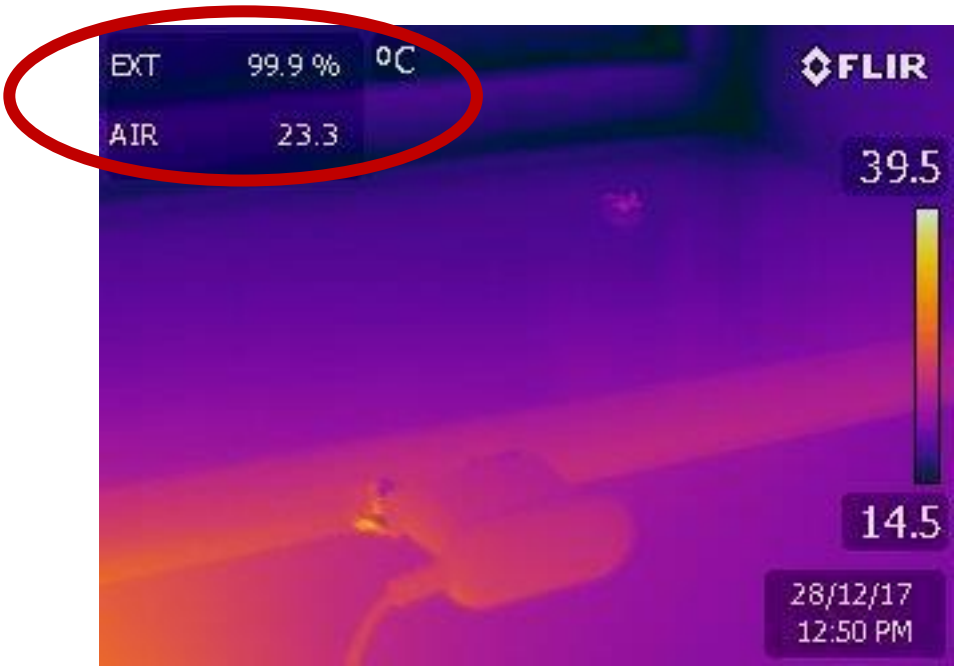
38 This house had cavity wall insulation poorly installed which caused internal condensation and mold growth



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 poorly insulated (cold) loft (mould growth above)



41 The IR camera recording 99.9% moisture content through a blue tooth conductive meter 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 and skirting.
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 thereby exposing leaks