Slide 1

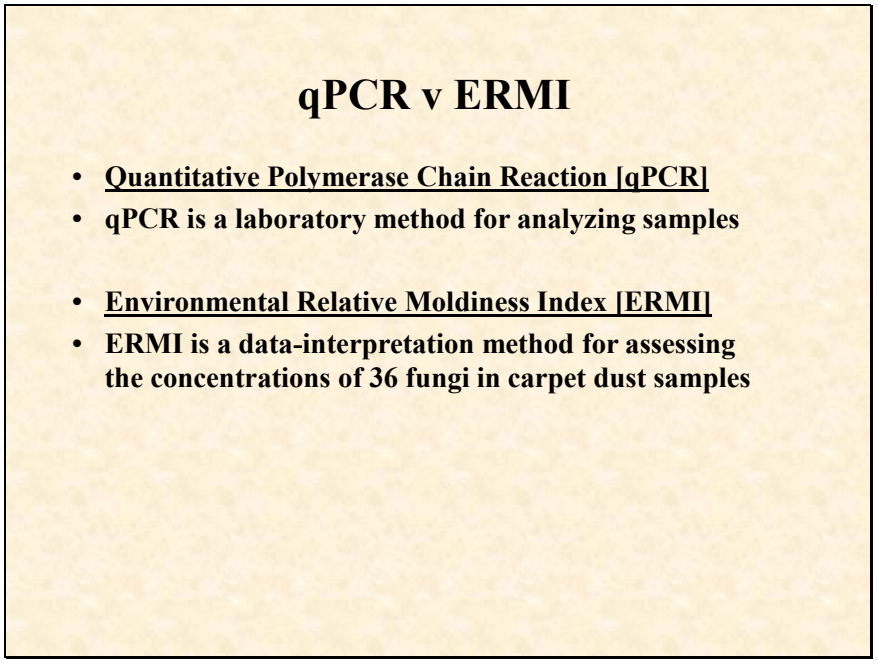
Limitations of the ERMI Carpet Sampling Method

Joe C. Spurgeon, Ph.D.
jospur46@gmail.com
www.expertonmold.com

1

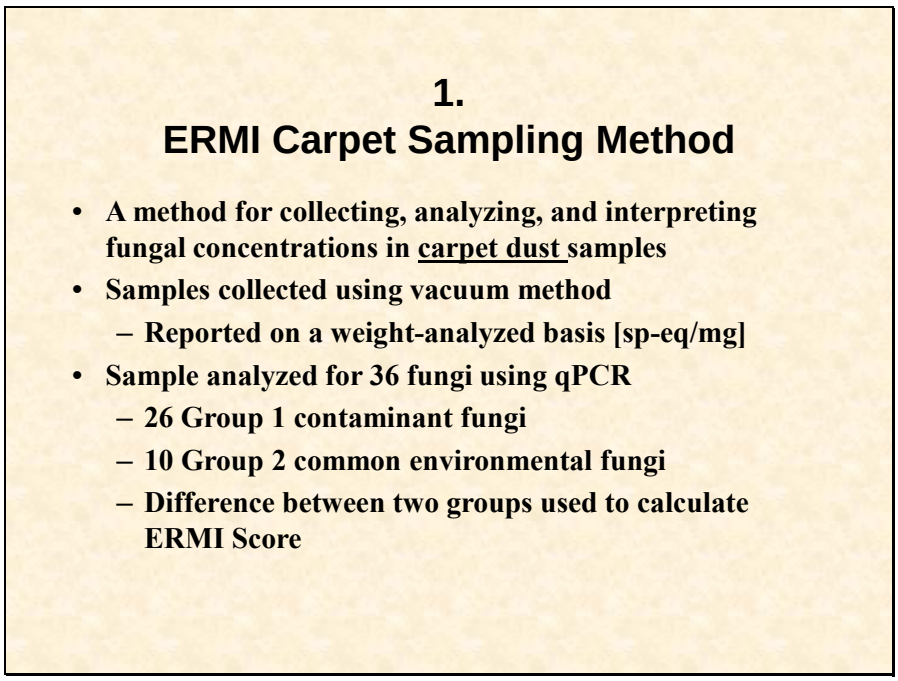
ERMI is a method for collecting carpet dust samples, analyzing the collected dust for 36 fungi by qPCR [DNA analysis], and interpreting the sample results by comparing the sample result to the results obtained for about 1,100 carpet dust samples collected in a large multi-city study.

Slide 2



qPCR is a laboratory method for analyzing the sample.
ERMI is a method for interpreting the sample results.

Slide 3



Section 1 describes the ERMI method.
Sample results are reported as “spore-equivalents” [sp-eq] rather than spores; typically dust samples are reported as sp-eq per milligram of dust [sp-eq/mg].
ERMI samples are reported on a weight-analyzed basis. Sample results may be reported on a weight-analyzed, total weight, or area basis. Published articles suggest that samples reported on an area basis were better correlated with occupant exposure potential.
ERMI samples are analyzed for 36 fungi, 26 Group 1 contaminant fungi and 10 Group 2 common environmental fungi. The numerical difference between the two groups is used to calculate the ERMI score.

Slide 4

Collecting ERMI Samples

1. **Vacuum 2 square meters of carpet - one in living room and one in bedroom.**

Courtesy of Steve Vesper

This is an illustration of the "standard" ERMI sampling method. A laboratory may issue a report in the ERMI format, but the ERMI method should only be applied to surface dust samples collected from carpets [not couches, air ducts, hard surfaces, etc.].

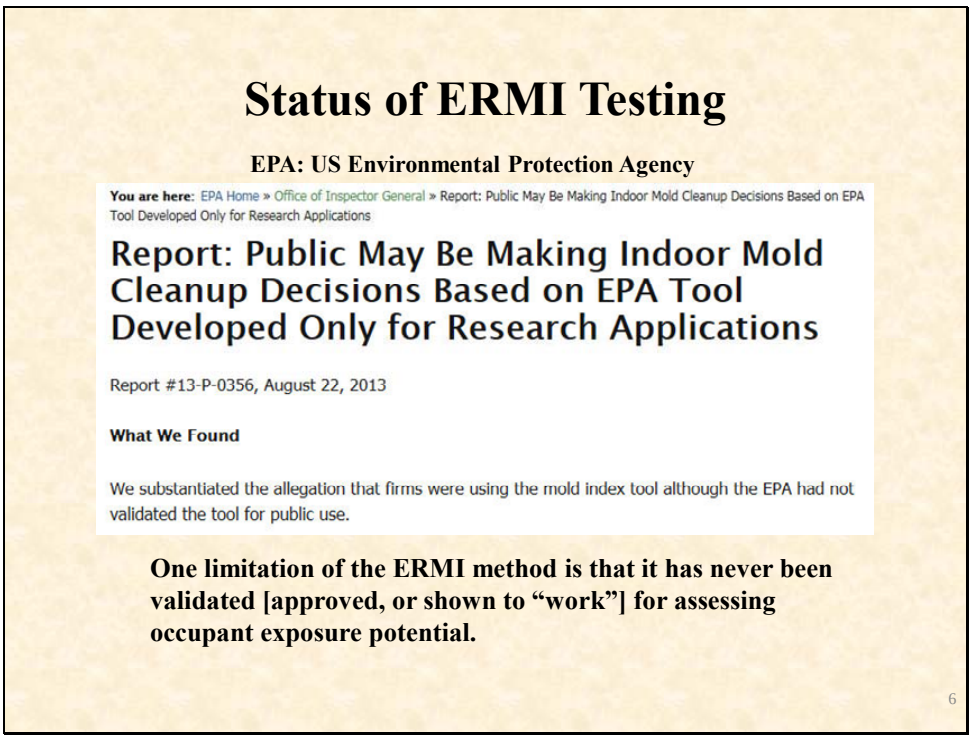
Slide 5

Data Presented

- **"Pseudo-ERMI" data, not ERMI data**
- **Carpet samples**
  - **Filter cassette – ERMI format – Area basis**
- **Common practice: Filter cassette – ERMI - Weight basis**

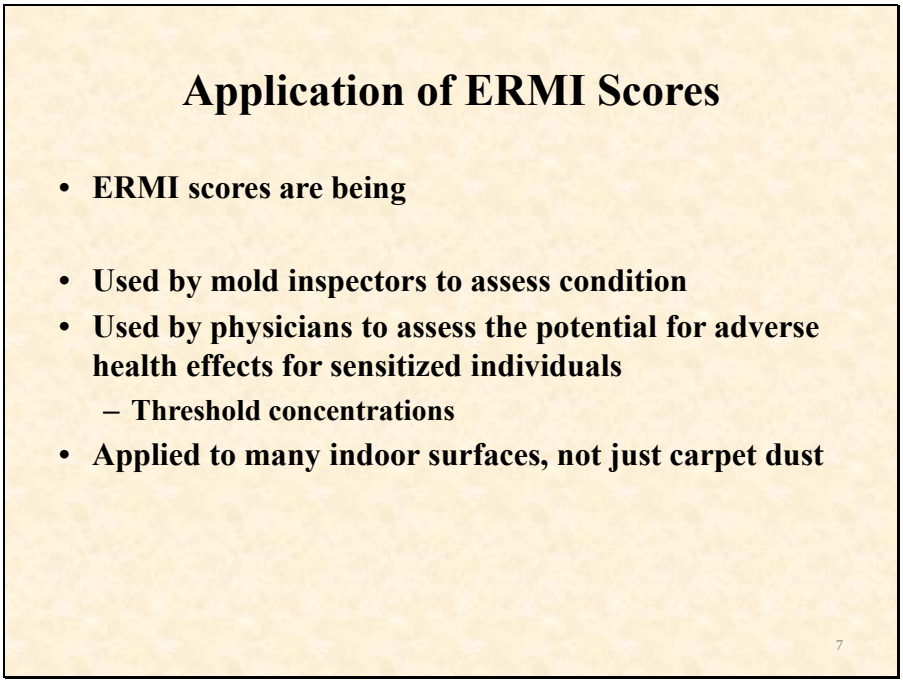
The ERMI sampling method is somewhat time consuming, so the mold inspector may use a faster micro-vacuum method [photo on right side]. However, that is not the "ERMI" sample collection method. The data discussed in this article were collected using the micro-vacuum method illustrated in the right-side photo. In addition, the sample results were reported by the laboratory on an area basis: spore-equivalents per 100 square centimeters [sp-eq/100 cm^2].

Slide 6



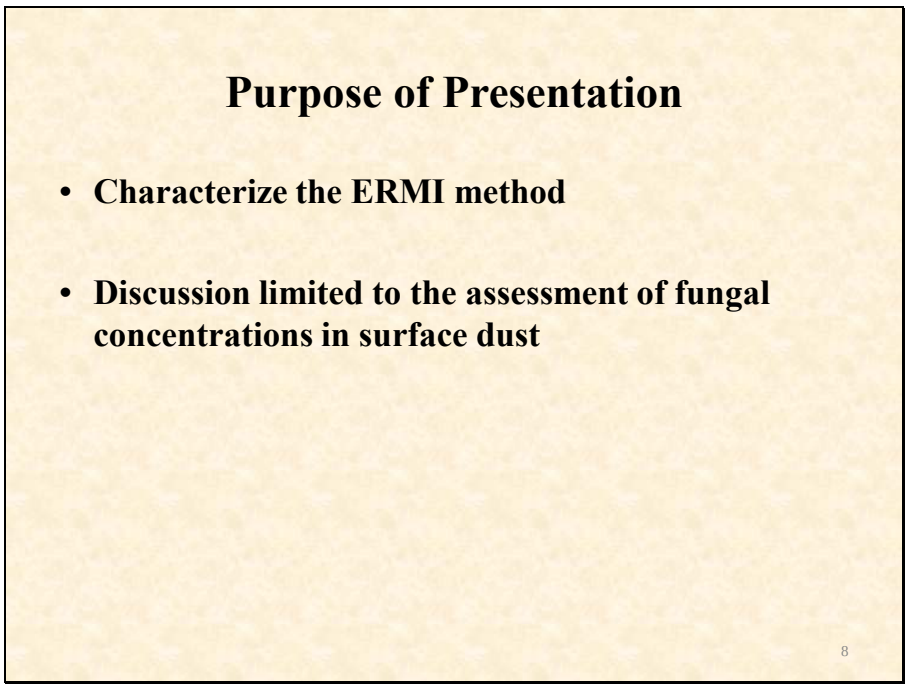
The qPCR method for analyzing mold samples is a sophisticated laboratory method. However, ERMI is just one of several methods that could be used to interpret the sample results; and EPA indicated in this notice that they do not consider the method to be ready for routinely applying it to consumer samples.

Slide 7



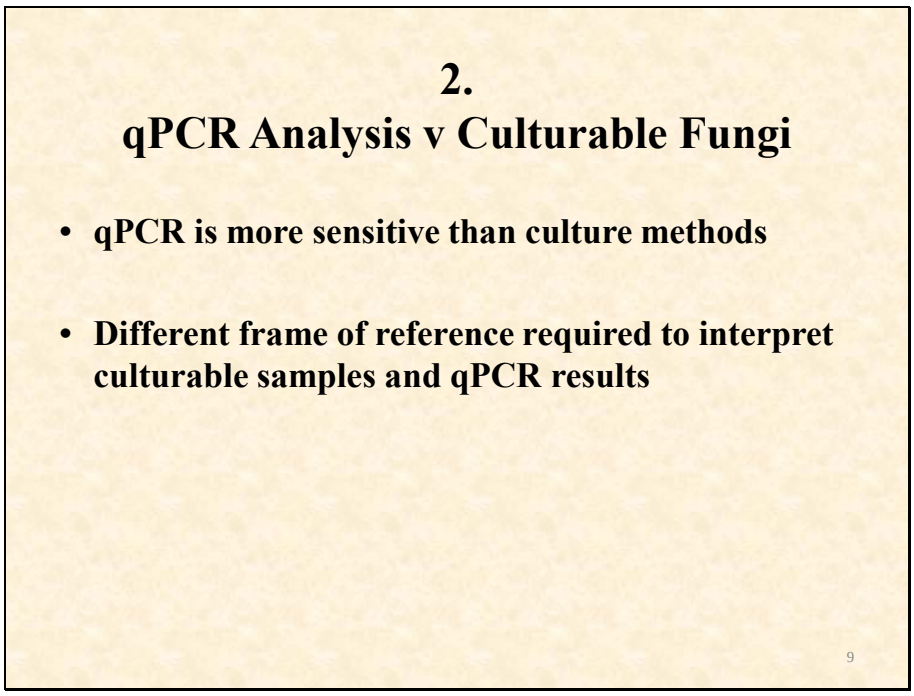
However, ERMI scores are used by mold inspectors and physicians to assess (1) the condition of the indoor environment, and/or (2) the potential for adverse health effects. In addition, ERMI scores are routinely assigned to samples collected from a multitude of surfaces, not just carpets.

Slide 8



A mold inspection may have either of two objectives, the assessment of (1) the condition of the indoor environment, or (2) occupant exposure potential. These are different objectives, and may require the use of different sample collection methods as well as different data interpretation methods. The consumer should make sure the mold inspector has the same objective as the homeowner.

Slide 9



Section 2 compares qPCR results with the results for culturable methods. The consumer should be aware that different methods may result in widely different concentration ranges.
The “numbers” a consumer sees in a qPCR report may be orders of magnitude higher than those reported for samples analyzed by culturable methods. The concentrations contained in a qPCR report may look rather frightening when compared to a report for culturable fungi, but may actually be rather average.

Slide 10

Air Delivery System
Total Fungi

LOCATION	qPCR Sp-Eq/in^2	Culturing cfu/in^2
Air Return	2,066,000	3,400
Air Return	4,103,000	3,900
Air Return	4,015,000	19,200
Air Supply	9,430,000	14,300
Air Supply	46,200	16,000
Air Supply	9,601,000	26,200

This is a comparison of total fungal concentrations for surface swab samples collected from three air supply ducts and three air returns. Each sample was analyzed by culturing on MEA media and by qPCR. The results were compared in this table. As indicated, there can be a dramatic difference between these two methods of analysis.

Slide 11

Air Delivery System
Aspergillus fumigatus

LOCATION	qPCR Sp-Eq/in^2	Culturing cfu/in^2
Air Return	1,200	200
Air Return	15,000	0
Air Return	24	0
Air Supply	620	200
Air Supply	12	0
Air Supply	0	0

These are the concentrations of *Aspergillus fumigatus* for the same six samples. These differences were less dramatic, but there was still a 3-fold to 6-fold difference for five of the six samples [one air return samples was substantially elevated by qPCR, but not by culturing].

Slide 12

Air Delivery System
Stachybotrys chartarum

LOCATION	qPCR Sp-Eq/in^2	Culturing cfu/in^2
Air Return	2,700	0
Air Return	2,300	0
Air Return	0	5
Air Supply	630	0
Air Supply	0	0
Air Supply	0	0

The table is a comparison of the same six samples for *Stachybotrys* concentrations. *Stachybotrys* may be detected more frequently, and at higher concentrations using qPCR because it is a more sensitive method compared to culturing.

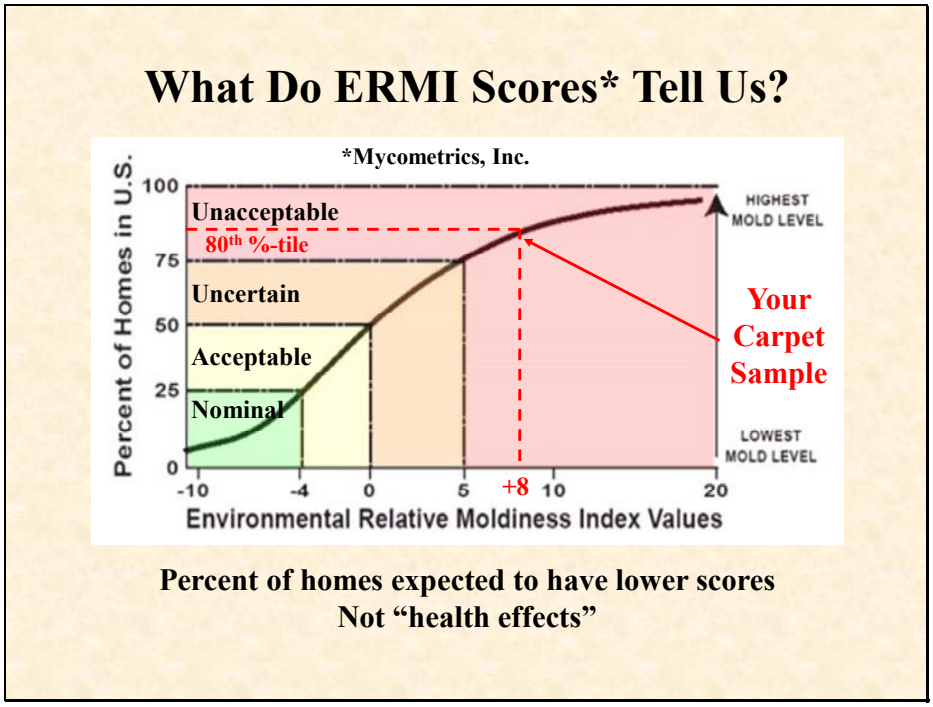
Slide 13

3.
What Is an Acceptable ERMI Score?

- **Guidance provided within the method**
  - **Associate quartile percentages with ERMI scores**
- **Additional guidance may be found on web sites**
  - **Chronic Inflammatory Response Syndrome [CIRS]**
    - » **ERMI score less than +2**
  - **Very sensitive individuals**
    - » **ERMI score less than -1**
  - **HERTSMI score less than 10: acceptable**
  - **HERTSMI score greater than 15: unacceptable**

Section 3 discusses how an ERMI report is typically interpreted by the mold inspector. The consumer should also be aware of how it is interpreted.
The only guidance provided for interpreting ERMI scores is the association of quartile percentages with the range of ERMI scores. It is implied that a scores of +5 [75th percentile] or higher are elevated.
Additional guidance for interpreting ERMI scores may be found on various web sites, as indicated in the slide.

Slide 14



This is an illustration of an ERMI graph. The bottom horizontal axis is the ERMI score, which varies from -10 to +20. The vertical axis is the percentage of homes in the US that are expected to have an ERMI score less than the score reported by the laboratory.
Common break-points in the ERMI graph occur at a score of -4 (25th percentile), 0 (50th percentile), and +5 (75th percentile).
For example, 75% of homes are expected to have an ERMI score of +5 or less. If your carpet had an ERMI score of +8, then about 80% of US homes are expected to have a lower score [so your carpet would have a high ERMI score]. A score between 0 and +5 may be classified as "uncertain", while a score higher than +5 would be "unacceptable".
The only association of ERMI scores with the potential for adverse health effects is on the right vertical axis: Mold Level. It is implied that the ERMI score is proportional to Mold Level, which would be expected to be associated with occupant exposure potential for non-sensitized individuals.

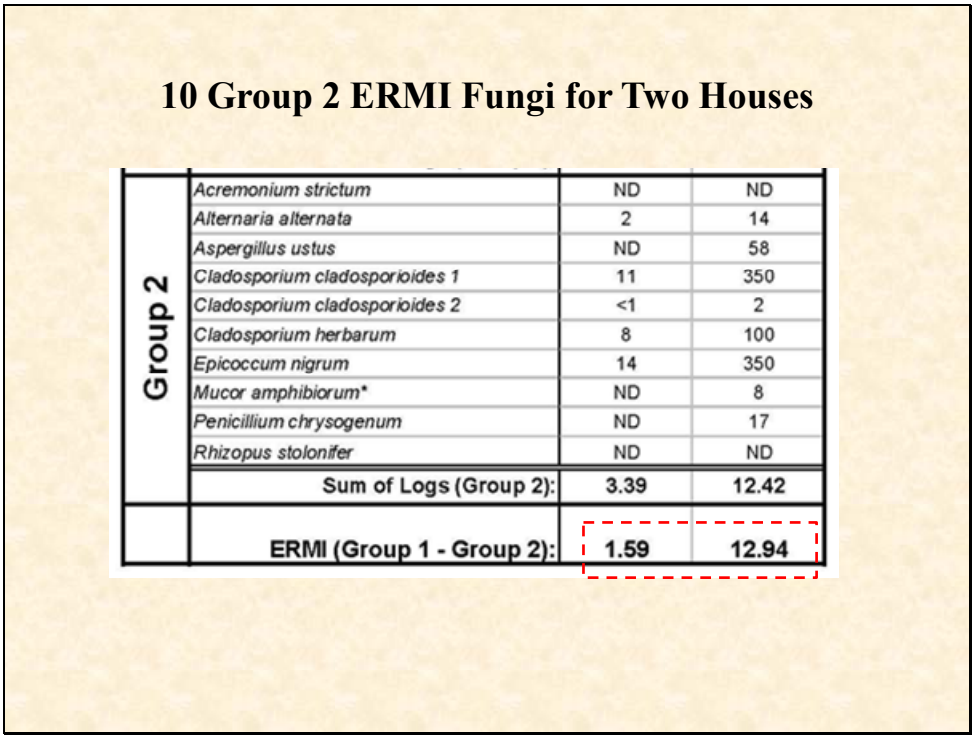
Slide 15

26 Group 1 ERMI Fungi for Two Houses

	Fungal ID \ Unit	Spore E./mg	Spore E./mg
Group 1	*Aspergillus flavus/oryzae*	ND	ND
	Aspergillus fumigatus	ND	1
	Aspergillus niger	ND	2
	Aspergillus ochraceus	5	9
	Aspergillus penicillioides	4	730
	*Aspergillus restrictus**	ND	ND
	Aspergillus sclerotiorum	ND	ND
	Aspergillus sydowii	ND	<1
	Aspergillus unquis	ND	8
	Aspergillus versicolor	ND	530
	Aureobasidium pullulans	680	390
	Chaetomium globosum	ND	ND
	Cladosporium sphaerospermum	7	26
	*Eurotium (Asp.) amstelodami**	1	150
	Paecilomyces variotii	ND	ND
	Penicillium brevicompactum	ND	170
	Penicillium corylophilum	ND	74
	*Penicillium crustosum**	ND	29
	Penicillium purpurogenum	ND	ND
	*Penicillium spinulosum**	ND	1
	Penicillium variabile	ND	3
	Scopulariopsis brevicaulis/fusca	ND	ND
	Scopulariopsis chartarum	ND	4
	Stachybotrys chartarum	ND	140
	*Trichoderma viride**	ND	<1
	Wallemia sebi	ND	460
	Sum of Logs (Group 1):	**4.98**	**25.36**

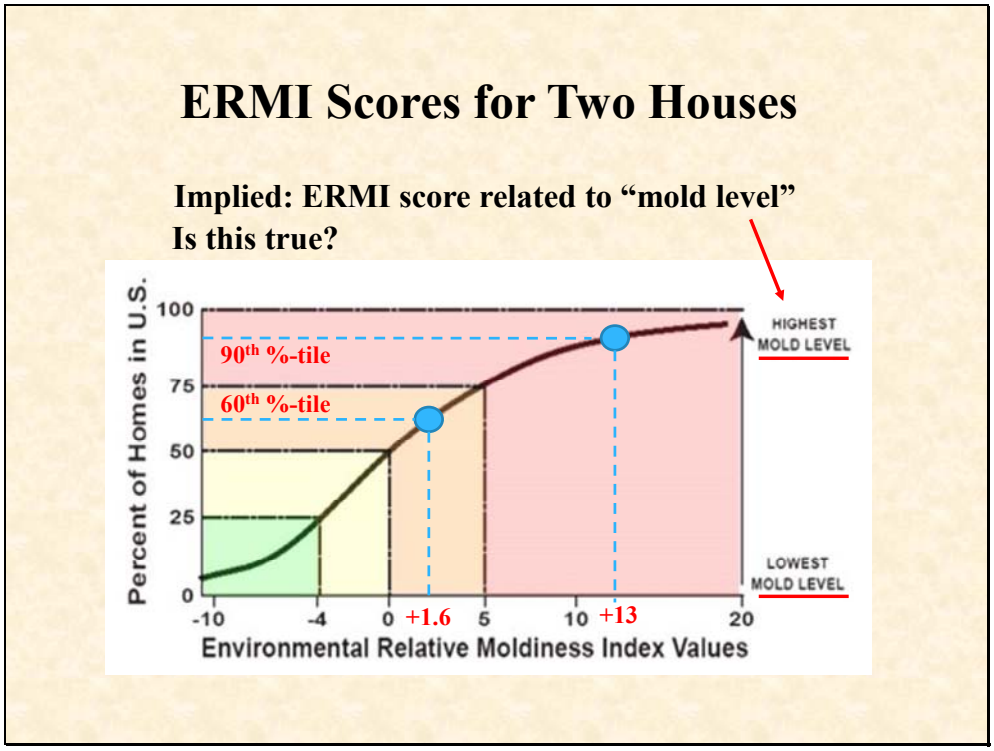
These are the 26 Group 1 contaminant fungi reported in an ERMI format [this is the top portion of an actual ERMI report from a laboratory]. One sample was collected from each of two houses [each column is a different house].

Slide 16



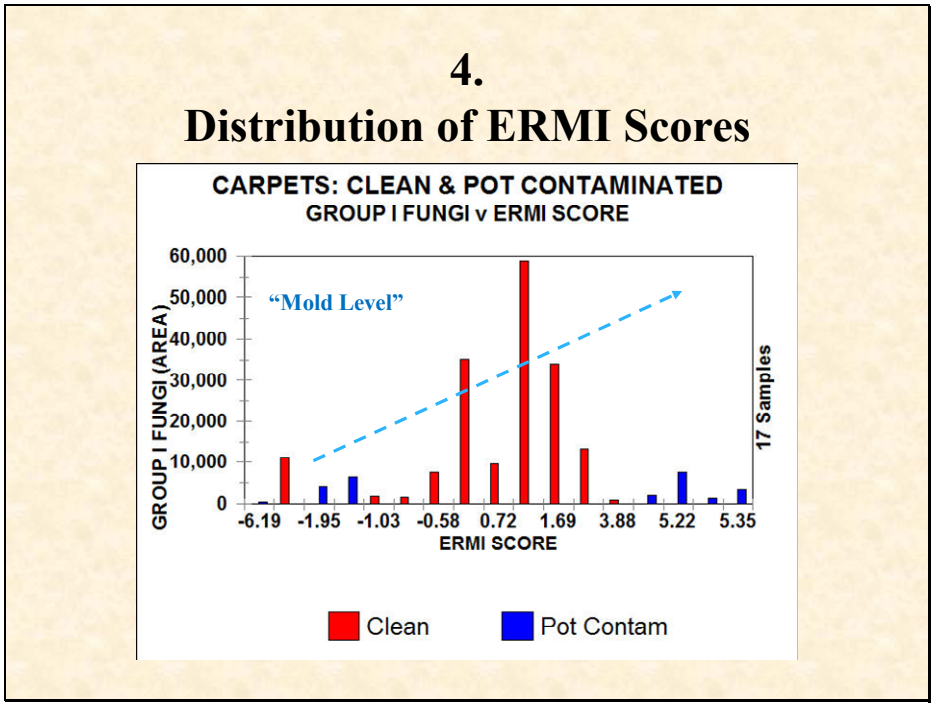
This is the lower portion of the same laboratory report, indicating the concentrations of the 10 Group 2 common environmental fungi as well as the ERMI scores for the two houses [+1.6 and +13].

Slide 17



The first house had an ERMI score of +1.6. That would place it at about the 60th percentile [60% of US homes are expected to have a lower ERMI score]. The interpretation would be "uncertain" [the carpet dust could be an issue, but not certain].
The second house had an ERMI score of +13. This would place this house at the 90th percentile [90% of US homes are expected to have a lower ERMI score]. Clearly, the results for this carpet were "unacceptable".
This discussion describes how an ERMI score may be interpreted. But, these interpretations were based on the assumption that the ERMI score was a measure of Mold Level. What if this assumption were not true?

Slide 18

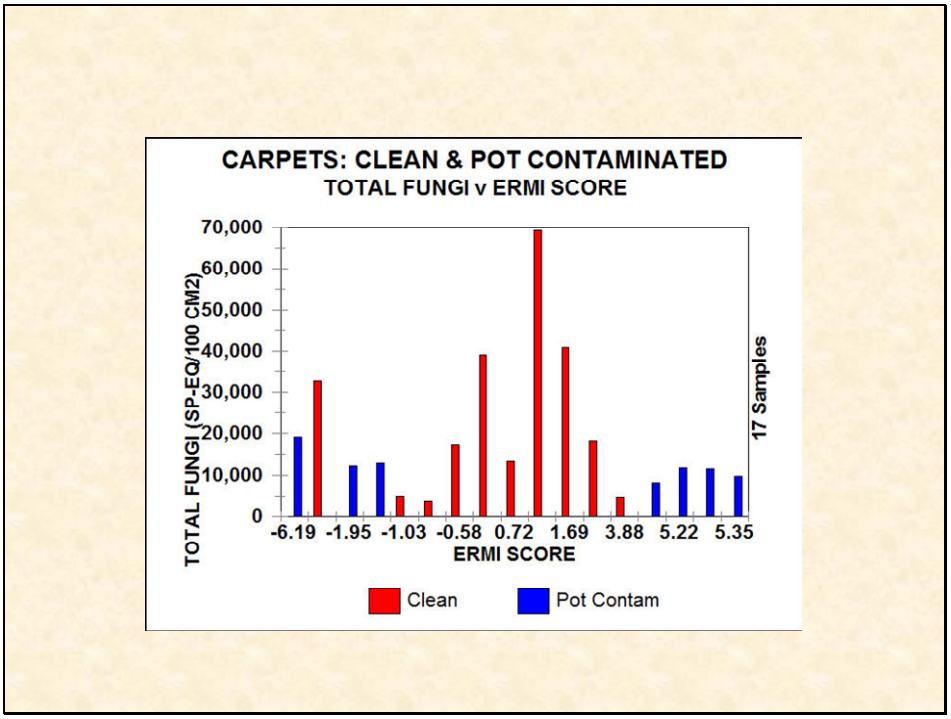


Section 4 explores whether or not ERMI scores are actually a measure of occupant exposure potential.

This graph illustrates the concentration of the Group 1 contaminant fungi versus the ERMI score for 17 carpet dust samples.

If the ERMI scores were proportional to the concentrations of contaminant fungi, the data should increase from the lower left to the upper right [similar to the blue dashed line]. This is not what happened. The highest concentrations of Group 1 contaminant fungi were clustered around an ERMI score of about "0".

Slide 19



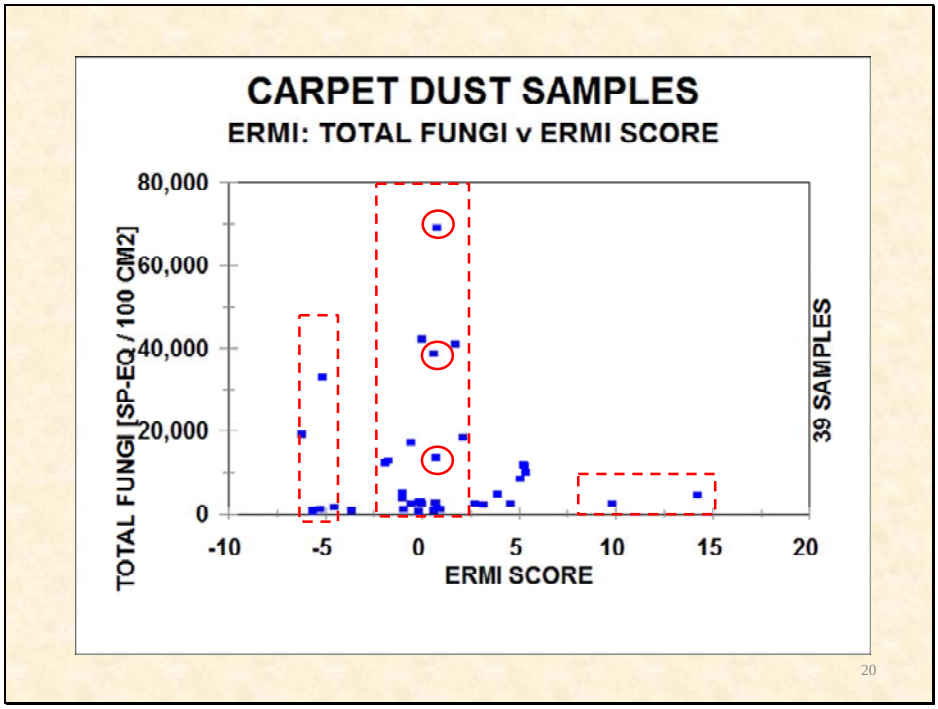
These are the concentrations of total fungi (all 36 fungi) versus the ERMI scores for the same 17 carpet dust samples. The same pattern was obtained as for the Group 1 fungi, essentially a normal distribution standardized at "0".

Neither the concentrations of contaminant fungi nor total fungi were proportional to the ERMI score. Again, the highest concentrations were clustered around an ERMI score of "0".

Second, all 17 samples had ERMI scores between -6 and +6. An ERMI score greater than +6 may only occur infrequently.

Conclusion: ERMI scores for the 17 carpet dust samples were not proportional to fungal concentration.; and fungal concentration was expected to be a measure of occupant exposure potential [higher concentrations mean a higher exposure potential].

Slide 20



Fungal concentration versus ERMI score:
Score = -6: Concentrations ranged from 500 to 34,000 [68-fold range]
Scores = -2.5 to +2.5: Concentrations ranged from 700 to 69,000 [99-fold range]
Scores = +9 & +14: Low concentrations of 1,000 & 5,000
The point: Fungal concentrations were presumed to be a measure of occupant exposure potential; but, ERMI scores were not representative of fungal concentrations; therefore, ERMI scores were not a good measure of occupant exposure potential.

Slide 21

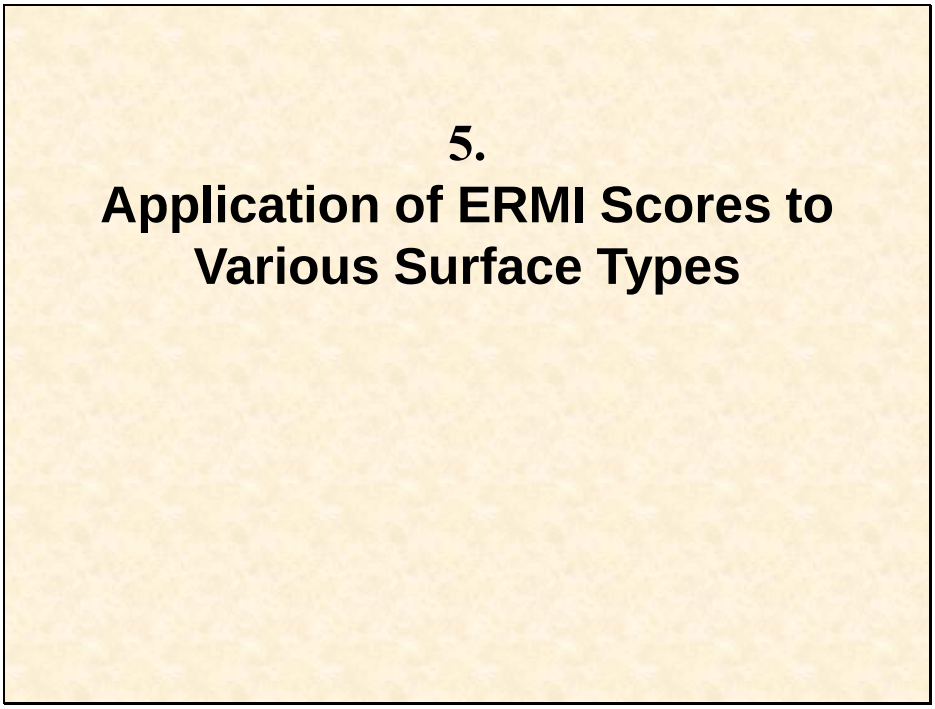
Fungal Concentration v ERMI Score

39 Carpet Dust Samples

ERMI scores did not change with a 68-fold and 99-fold variation in the concentration of total fungi

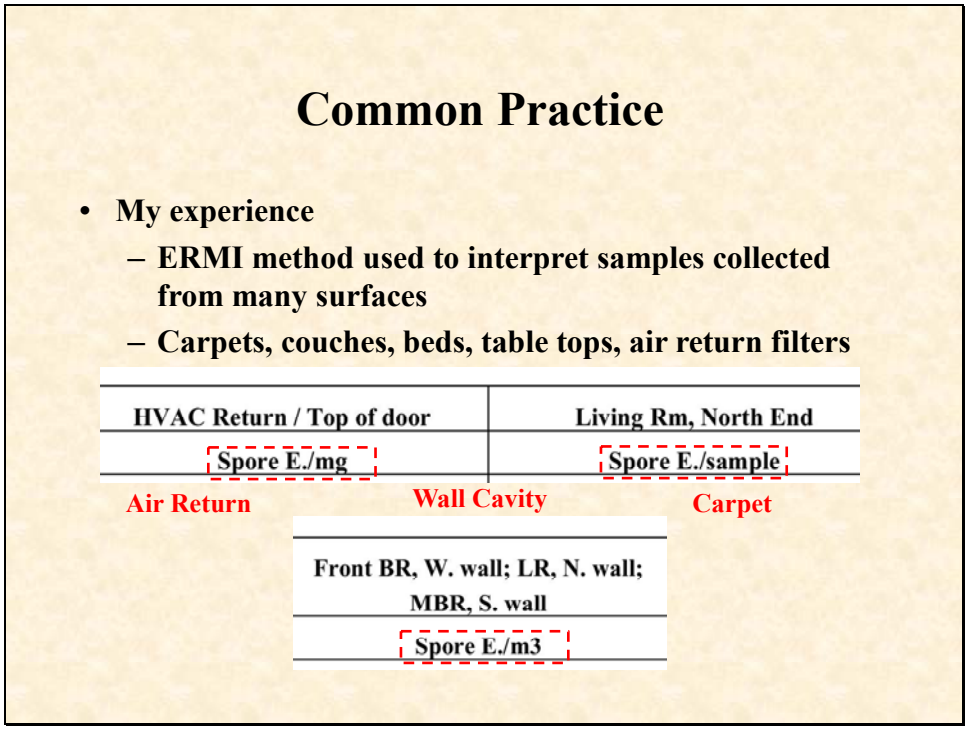
The ERMI Score was NOT associated with "Mold Level" for these samples

Slide 22



Section 5 discusses the reasons that an ERMI score, if it is used, should only be applied to carpet dust samples and not samples collected from other surfaces [couch, air duct, table top, etc.].

Slide 23



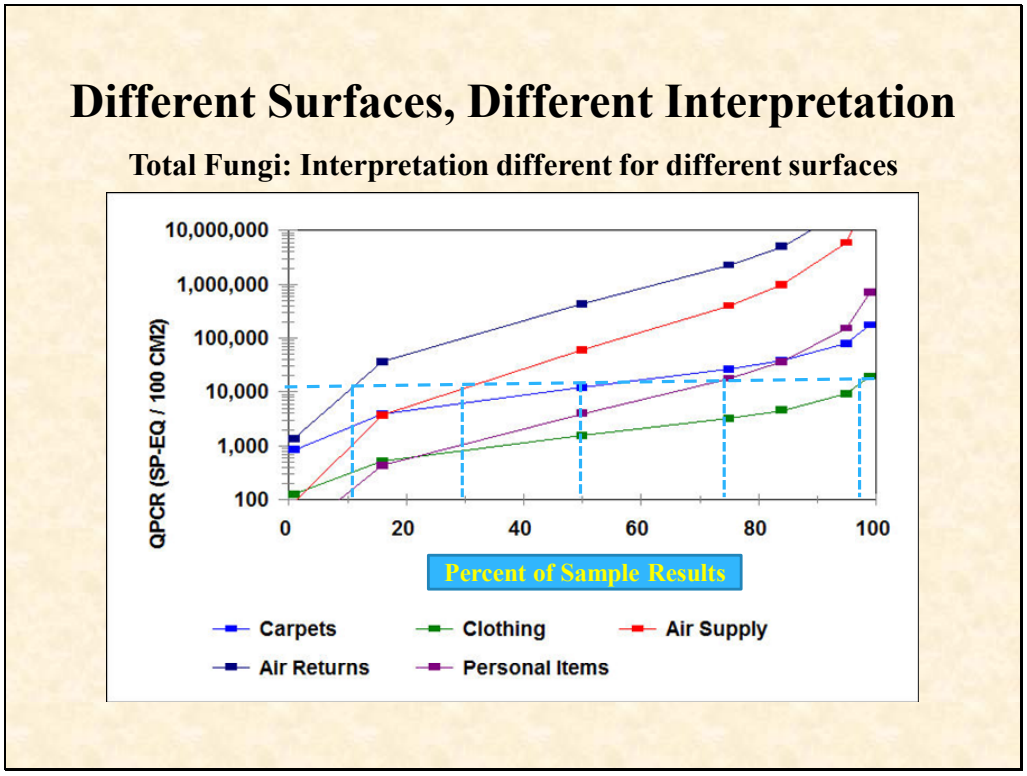
These are the headers from actual ERMI reports issued by laboratories. They indicate that ERMI scores are routinely reported for samples collected from various surfaces. But, should they be?

Limited Application

- **ERMI scores may ONLY be applied to CARPET DUST samples**

AND THIS IS WHY =>

Slide 25



This figure is a little “busy”, but very informative. The horizontal bottom axis is similar to the vertical axis of the previous ERMI graphs. It indicates the percentage of samples that are expected to be less than the concentration on the left vertical axis. For example, assume the laboratory reported a total fungal concentration of 10,000 sp-eq. How is that concentration interpreted? This is the problem.

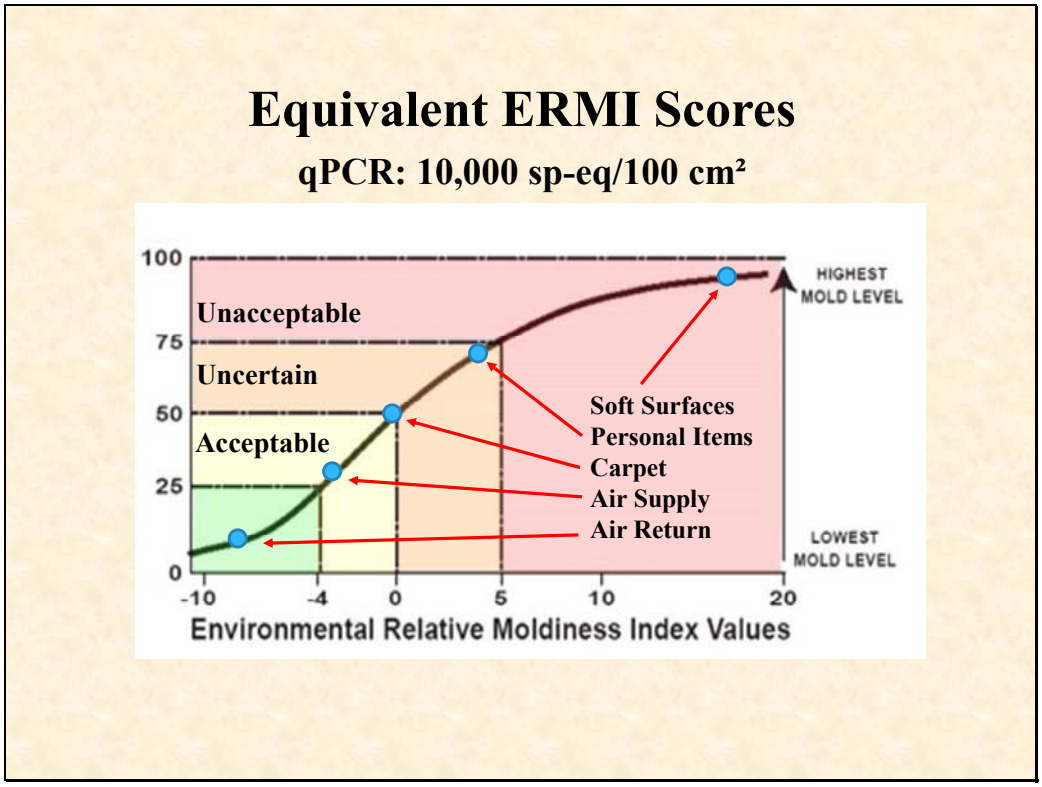
If the sample were collected from an air return filter, then only 10% of air returns would be expected to have a lower concentration. So it would be a low concentration, and not an issue.

If the sample had been collected from a carpet, then it would be the 50th percentile. So half the carpets would be expected to have more fungi and half less fungi; a typical result and also not an issue.

If the sample had been collected from a soft surface (clothing), it would be the 95th percentile; and the interpretation would be “substantially elevated”.

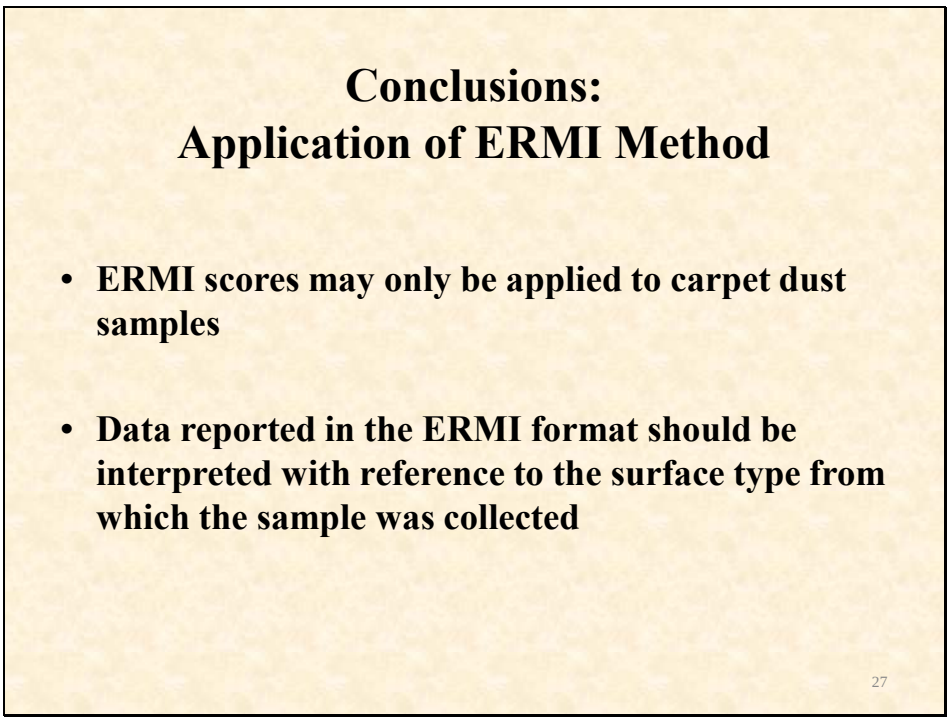
Conclusion: The laboratory report cannot be interpreted without reference to the surface from which the sample was collected.

Slide 26



This graph simply positions a concentration of 10,000 sp-eq on the ERMI graph according to the surface type from which the sample could have been collected. A concentration of 10,000 sp-eq on an air return would be a nominal concentration, while it would be substantially elevated if collected from a soft surface item.

Slide 27



A reported concentration of 10,000 sp-eq, for example, cannot be used to assess the condition of the indoor environment without (1) knowing the type of surface that was sampled, and (2) referencing the interpretation of that concentration to the “distribution of concentrations” for that surface type.

Slide 28

The ERMI Method

- **Vacuum sampling method is not user-friendly**
  - **Micro-vac methods are simpler and faster**
- **Sample type**
  - **ERMI may only be applied to carpet dust samples**
- **What do ERMI scores tell us?**
  - **Percent of homes expected to have lower scores**
- **Were ERMI scores related to occupant exposure potential?**
  - **No, if exposure potential ≈ fungal concentration**
- **Were ERMI scores related to threshold limits for sensitized individuals?**
  - **10^{th} %-tile concentrations occurred over a range of ERMI = -6 to +5 [CIRS <= +2]**

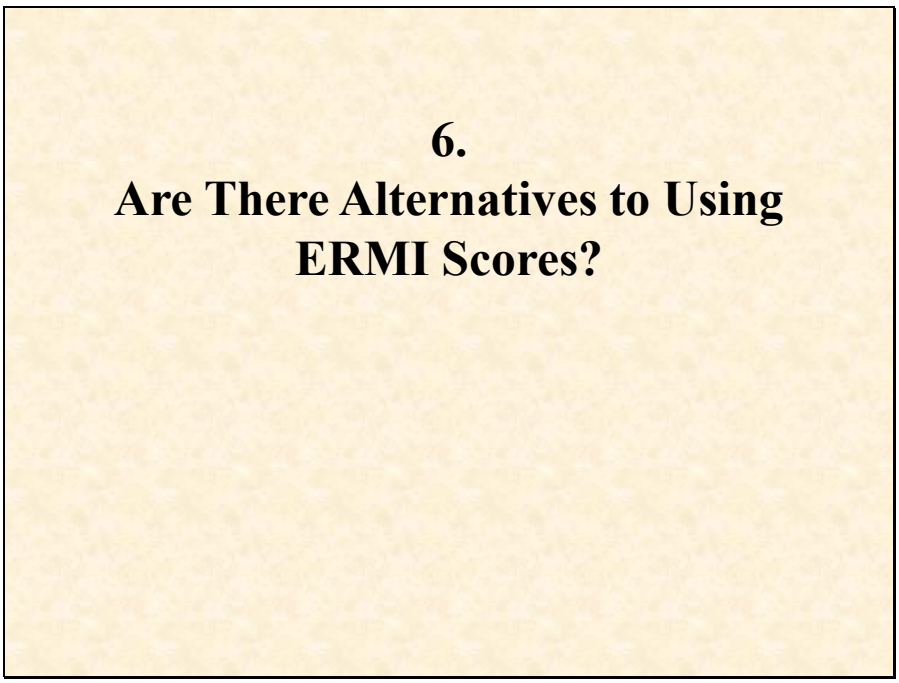
28

If individuals with extreme sensitivities or are immune compromised are not present in the indoor environment, then it may be presumed that increasing amounts of mold represent an increasing occupant exposure potential. However, sensitized or immune compromised individuals may react when the contaminant of concern exceeds a threshold concentration, so this presumption is not valid for those individuals. The discussions in this presentation do not address issues related to sensitized or immune compromised individuals.

Primary Limitations of ERMI Scores

- **ERMI scores were only applicable to carpet dust**
  - **Not applicable to other surfaces**
- **ERMI scores were not uniquely related to "mold level" [fungal concentration]**
  - **Similar ERMI score for a 100-fold variation in fungal concentration**
- **ERMI scores tell us the percent of homes expected to have lower or higher scores**
  - **Not a measure of carpet condition [clean or replace?]**
  - **Not a measure of occupant exposure potential**

Slide 30



Section 6 discusses alternatives to using ERMI scores to assess the presence of contaminant mold in the indoor environment. If ERMI scores have limitations, then is there a better alternative?

Slide 31

Fungal Concentration [FC]

- **Can FC be applied to surfaces other than carpets?**
  - **Yes. Carpets, HVAC system, surface dust, air samples**
- **Is FC related to occupant exposure potential?**
  - **Yes, if exposure potential ≈ fungal concentration**
- **Were FC related to threshold limits for sensitized individuals?**
  - **Carpets with less than a 10^{th} percentile concentration of ERMI fungi could be identified**
  - **Yes, if "sensitizing potential" of dust is different for 700 sp-eq/100 cm^2 and 70,000 sp-eq/100 cm^2**

31

The fungal concentration in the indoor environment is typically considered to be a measure of both condition and occupant exposure potential. Therefore, why not use fungal concentration as a direct measure of both condition and occupant exposure potential?

Slide 32

The "CAP" Method

- **The CAP method uses fungal concentrations as a measure of condition and occupant exposure potential**
- **It is based on qPCR analysis of surface dust, so provides the same information as ERMI**
- **It may be applied to any surface type, a limitation of ERMI**
- **It may reduce costs compared to ERMI since only 2, 4, 8, or 14 fungi are included compared to the 36 ERMI fungi**

32

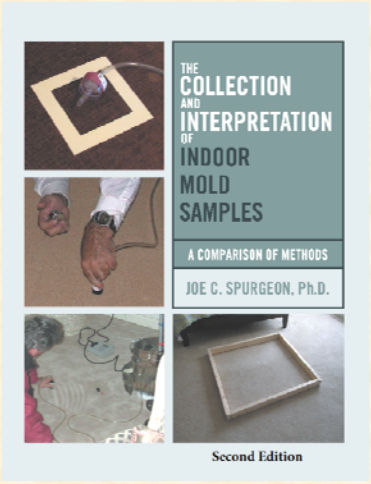
The CAP method, which is described in an accompanying presentation, is a continuation of this presentation.

Slide 33

Limitations of the ERMI Carpet Sampling Method

Joe C. Spurgeon, Ph.D.

jospur46@gmail.com
www.expertonmold.com



33

These concepts, and others related to mold, are discussed in more detail in the referenced book, which is available on the listed web site. The book is intended for use by trained, experienced personnel working in the mold industry.