16TH IAQA & ANNUAL MEETING

IE3 INDOOR ENVIRONMENT & ENERGY EXPOSITION
FEATURING ACCA AND RESNET

Effects of Sampling Time and Data Interpretation Methods on The Quality of Airborne Data

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Two Mini-Presentations

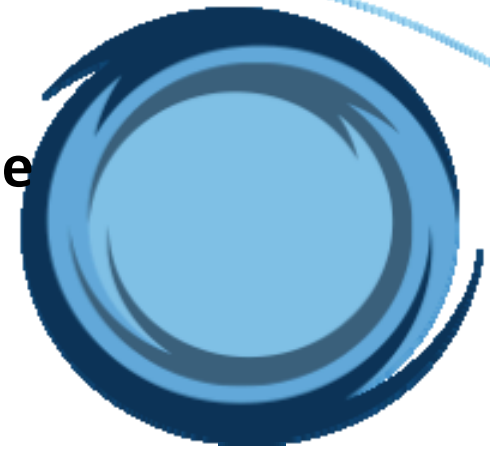
1. Effects of Sampling Time on Data Quality
2. Indoor-Outdoor Comparisons & Data Quality

Questions About Sampling Time

- [1] What is a long-term sample?
- [2] Can we even collect long-term samples?
  Theoretical concept or practical option?
- [3] Why should we care?
  Does sampling time actually affect data quality?

[1] NIOSH (Nat. Insti. of Occup. Safety and Health)

- Published sampling strategy manual in 1977
  - "Occupational Exposure Sampling Strategy Manual"
  - Pub. 77-173: Google for free download
- Section 3.3 defines long-term samples as those collected for 60 minutes or longer
  - Long-term samples – preferred method
  - Short-term "grab" samples – least desirable
    - Typical for mold



[2] Are Long-Term Samples A Practical Option?

- **Yes. Long-Term Spore Samples Have Been Collected Since at Least 1986***
- **Personally – since 2003 [10 years]**

*** Palmgren, L., G. Strom, G. Blomquist and P. Malmberg: Collection of airborne microorganisms on Nucleopore Filters, estimation and analysis - CAMNEA method.**
J. Appl.Bacteriol., 61:401-406 (1986)

[3] Limitations of Short-Term Samples?

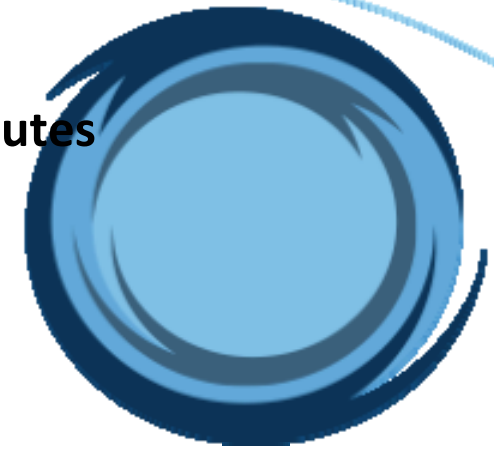
- (A) Detecting Problems Is Harder
  - Greater Variability => More False Negatives
- (B) Interpreting Data Is More Difficult
  - Poor Reproducibility => Poor Discrimination
- (C) False Assessment of Occupant Risk
  - Poor estimate of average concentration
  - Average concentration => Adverse effects

Examples Illustrating The Effects of Sampling Time

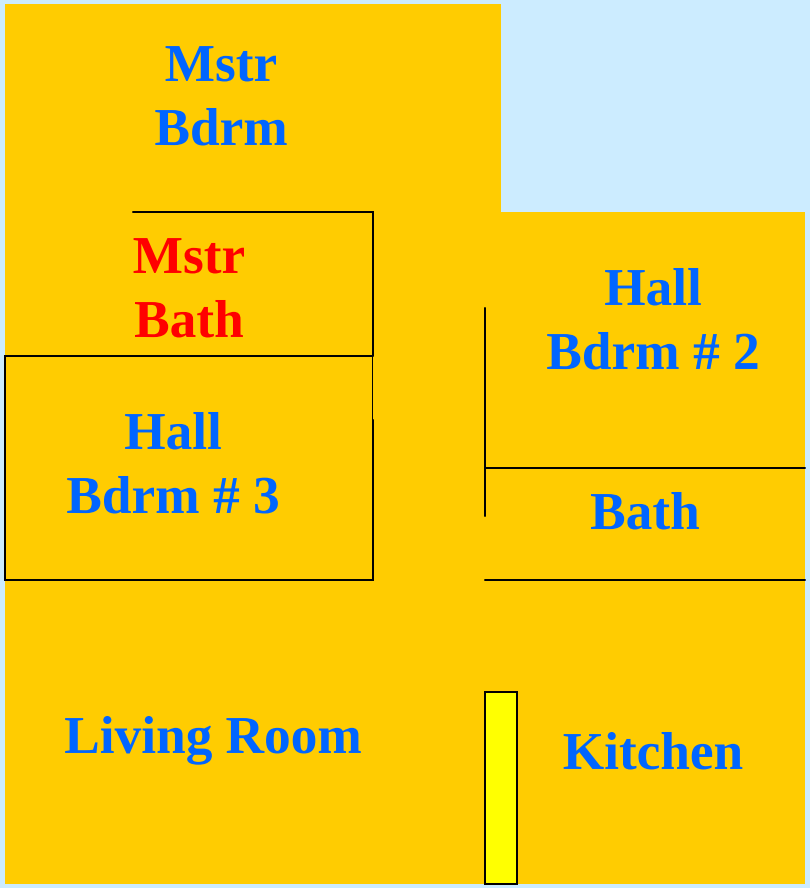
- [A] Problem Detection
- [B] Data Interpretation
- [C] Occupant Risk

[A] Detecting The Problem

- **Problem Operating Room in a Hospital**
  - **Surgeons refusing to operate**
  - **10-min Air-O-Cell samples**
    - **"No problem"**
    - **Physicians not satisfied**
  - **A 3-hour filter-cassette sample**
    - **4 *Asp/Pen* spores [25 spores/m^3]**
      - **Detecting one *Asp/Pen* spore every 45 minutes**
    - **Recommended thorough inspection**
  - **Result: Two walls were remediated**



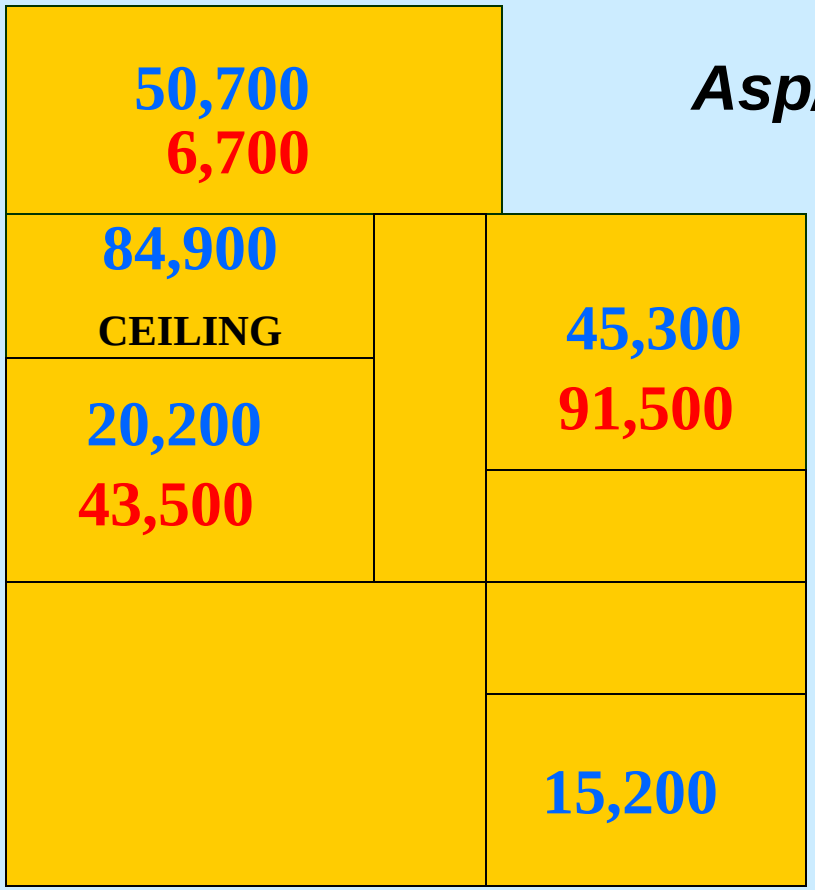
[B] Interpreting The Data:
Collapsed Ceiling in Master Bathroom



Ceiling had been repaired, but no remediation

Filter cassette (FC) and Air-O-Cell (AOC) samples collected

Concurrent 60-minute FC [Blue] and 5-minute AOC [Red] Samples



***Asp/Pen* Spores (sp/m³)**

Are the results consistent with incident history?

Confidence when interpreting short-term & long-term samples?

[C] Assessing Occupant Risk

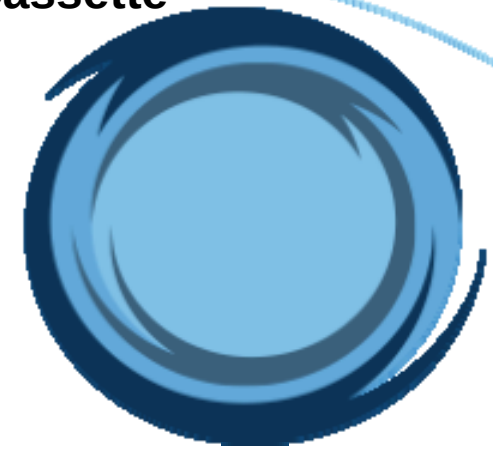
SAMPLER	AOC (5 MIN)	FC (10 MIN)
Samples	143	122
Median	585	674
Average	5,040	3,550

No statistical difference between median concentrations for samplers

AOC = Air-O-Cell
FC = Filter Cassette

Comparing Distributions [Database Method]

Conclusion: Any differences in next slide were not due to sampler



[C] Assessing Occupant Risk

SAMPLER	FC (10 MIN)	FC (60 MIN)
Samples	122	75
Median	674	[4.5x] 2,697
Average	3,550	[5.5x] 23,550

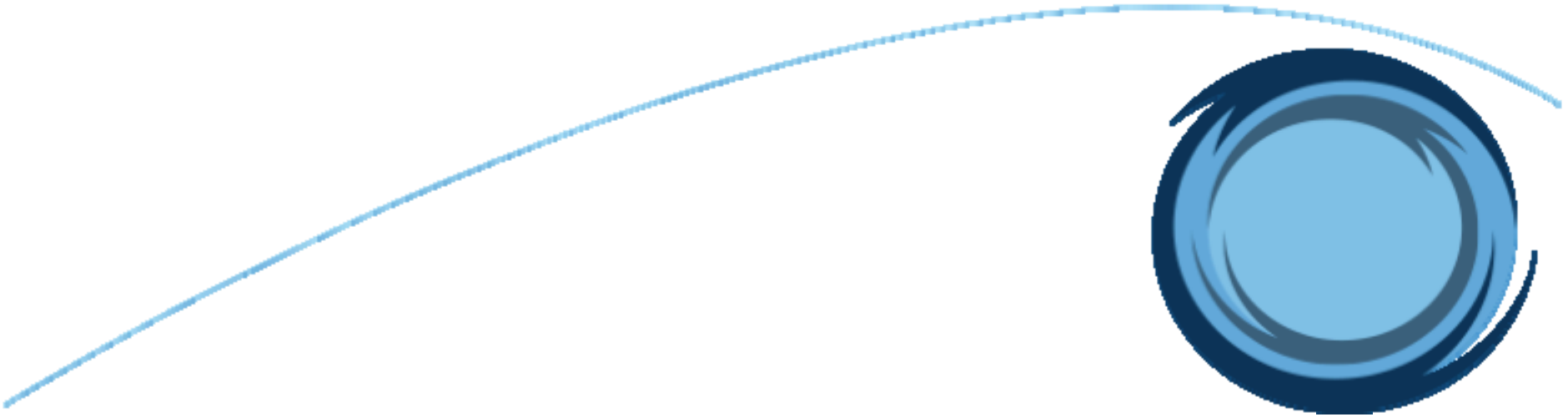
Significant statistical difference between median concentrations for sample times

Comparing Distributions [Database Method]

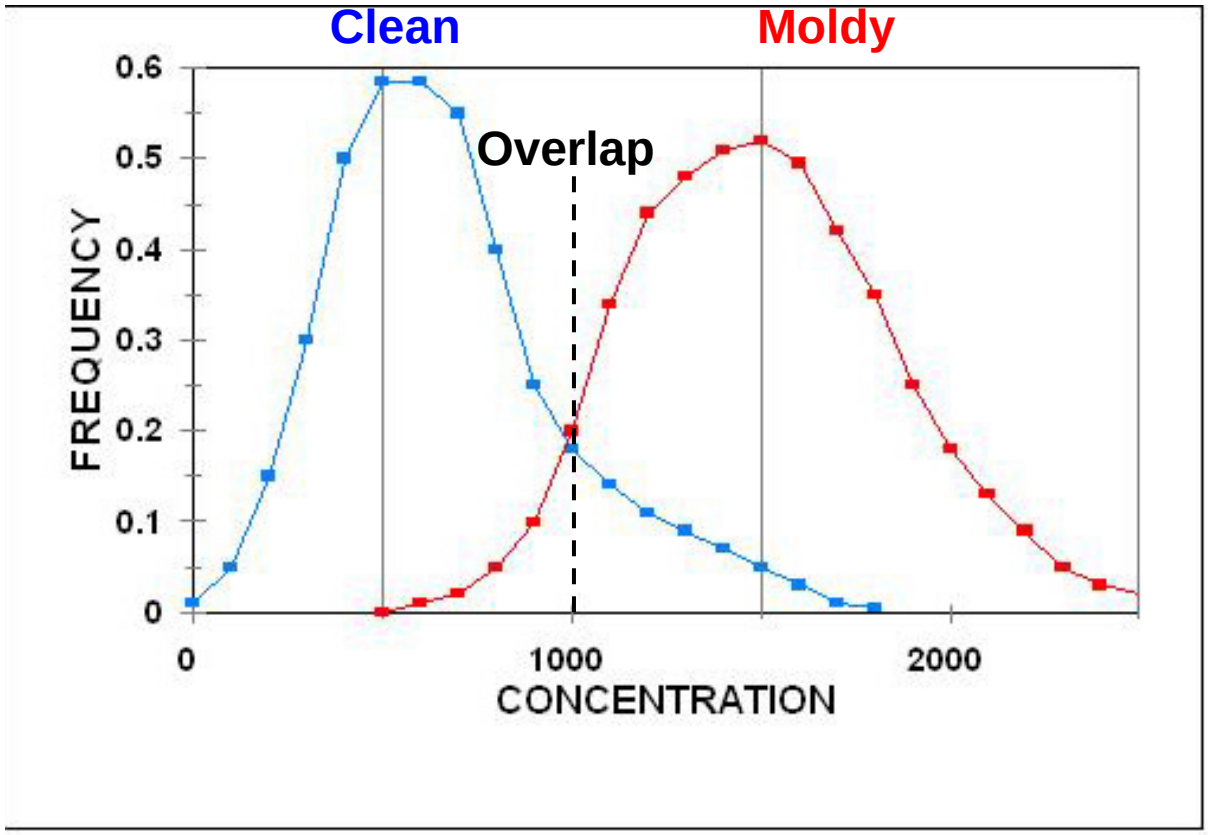
AOC = Air-O-Cell **FC = Filter Cassette**

Differences in median concentrations due to sample times – theoretically expected result (Rappaport et al)

Can We Explain These Differences Between Short- and Long-Term Samples?



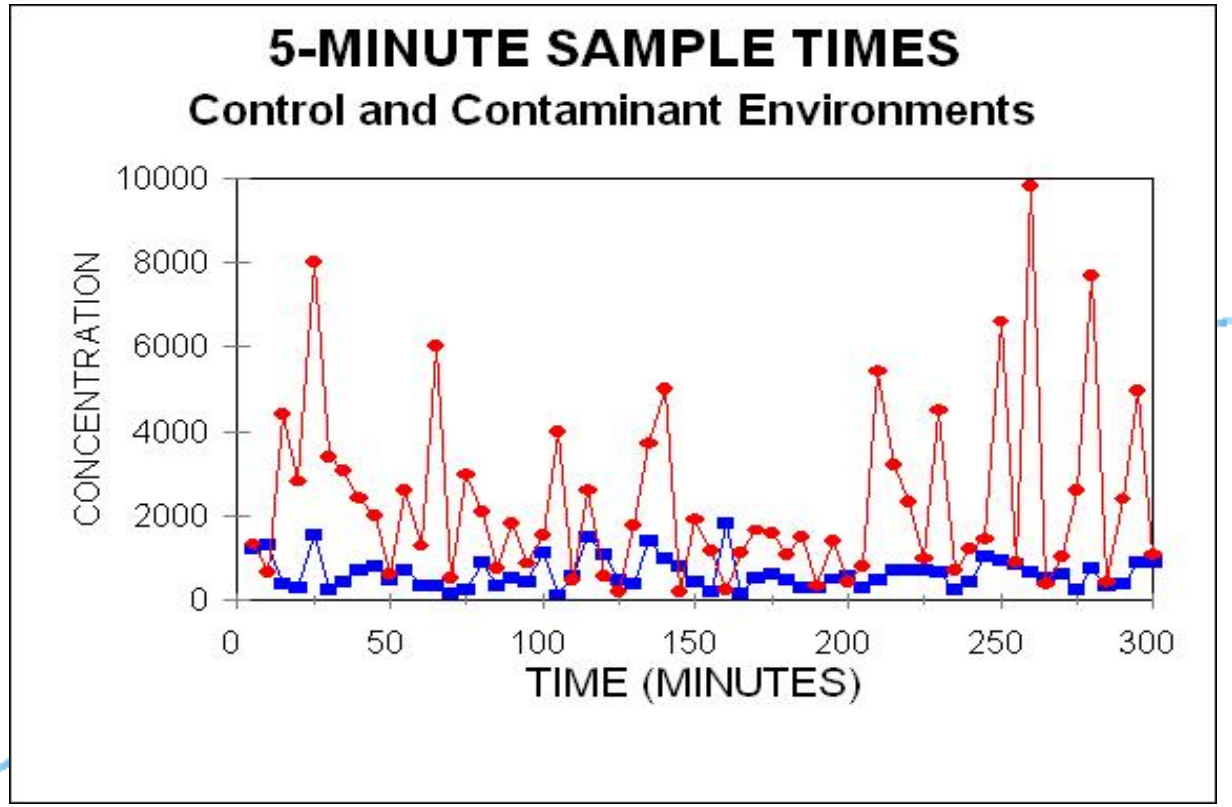
Two Example Distributions



What do "clean" & "moldy" distributions actually look like in the field?

Two Example Distributions:
Medians = 500 Sp/m³ and 2,500 Sp/m³

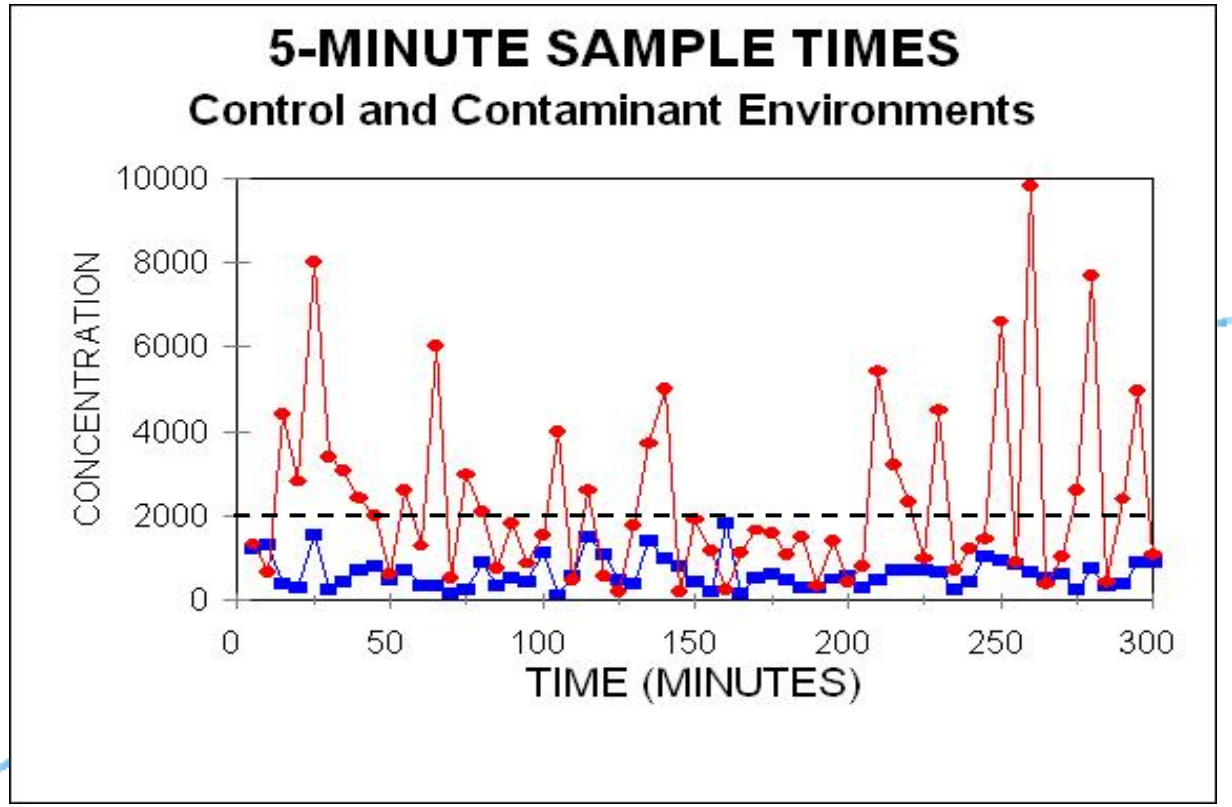
Medians Differ by A Factor of 5



1. **Constructed 60-sample distributions**
2. **Randomized data**
3. **Plot as consecutive 5-min samples**

Consequences?

Spores Are Particles, Not Gases



65 % < 2,000 S/m³
=> Chance of False Negative

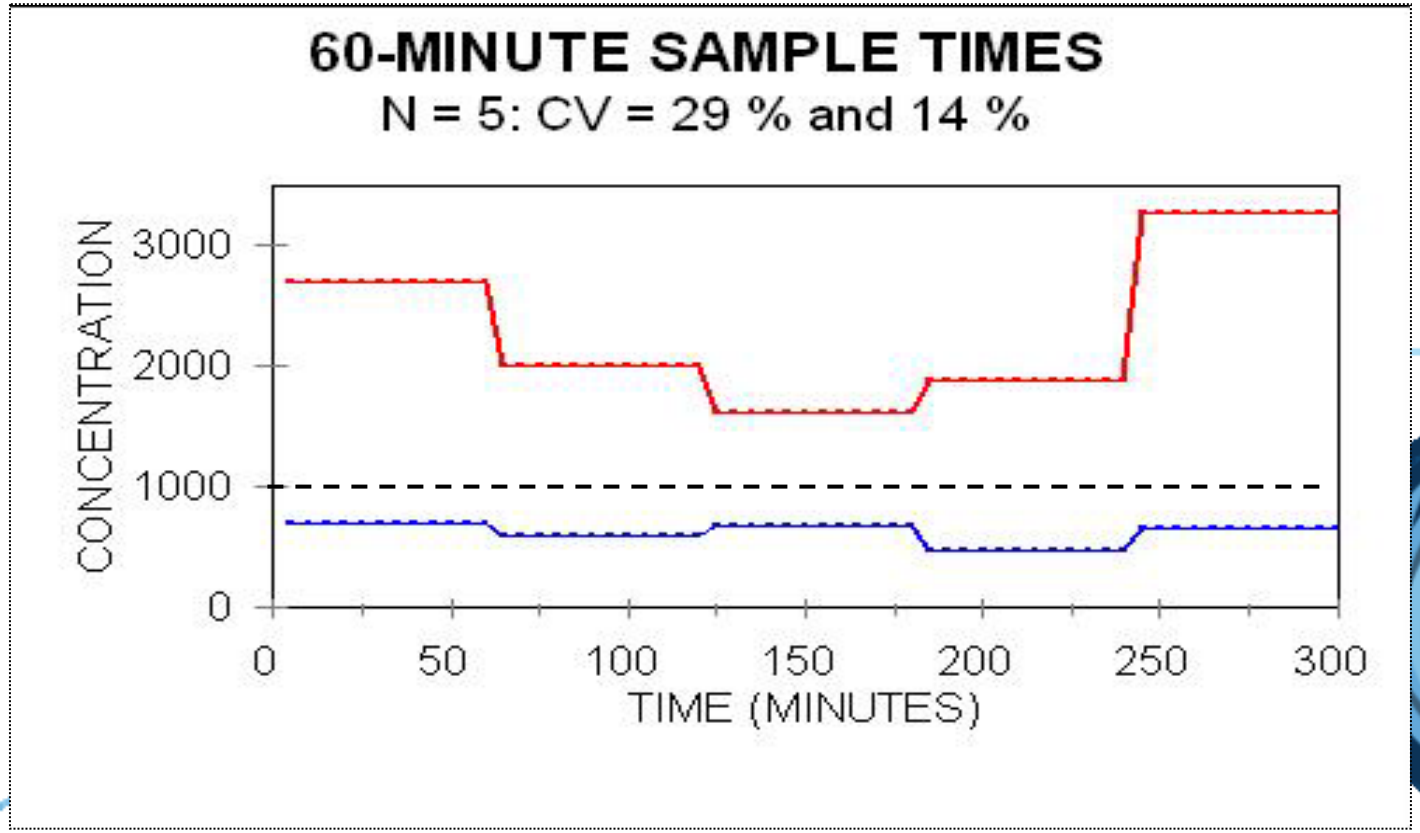
Short-Term Samples
=> Miss Peaks

Long-Term Samples
=> Capture Peaks

=> 35 % chance

Distributions as 60-Minute Samples

Clear Separation, No Overlap: Confident Interpretation



Confident interpretation if numerical guideline used

Interpreting Airborne Samples

It is often stated that airborne samples cannot be interpreted, that they are too variable.

My Opinion: Not true. It's short-term airborne samples that cannot be interpreted.

But – we only collect short-term samples, so we just assume this statement applies to all airborne samples – which it may not

Summary

Short-term samples can result in:

[1] A Failure to Detect the Problem [OR]

Higher percentage of false negatives

[2] Difficulty in Interpreting the Data [Apt]

Data just too variable

[3] Incorrect Assessment of Occupant Risk [Avg]

Short-term => miss peak concentrations

MY OPINION:

THE QUALITY OF SHORT-TERM AIRBORNE DATA, AND ALL WE HAVE IS SHORT-TERM DATA, IS SO POOR THAT IT IS NOT EVEN POSSIBLE TO ASSESS THE ASSOCIATION BETWEEN THE CONCENTRATIONS OF AIRBORNE SPORES AND ADVERSE HEALTH EFFECTS

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Comparison of Indoor To Outdoor Spore Concentrations In Residential Properties

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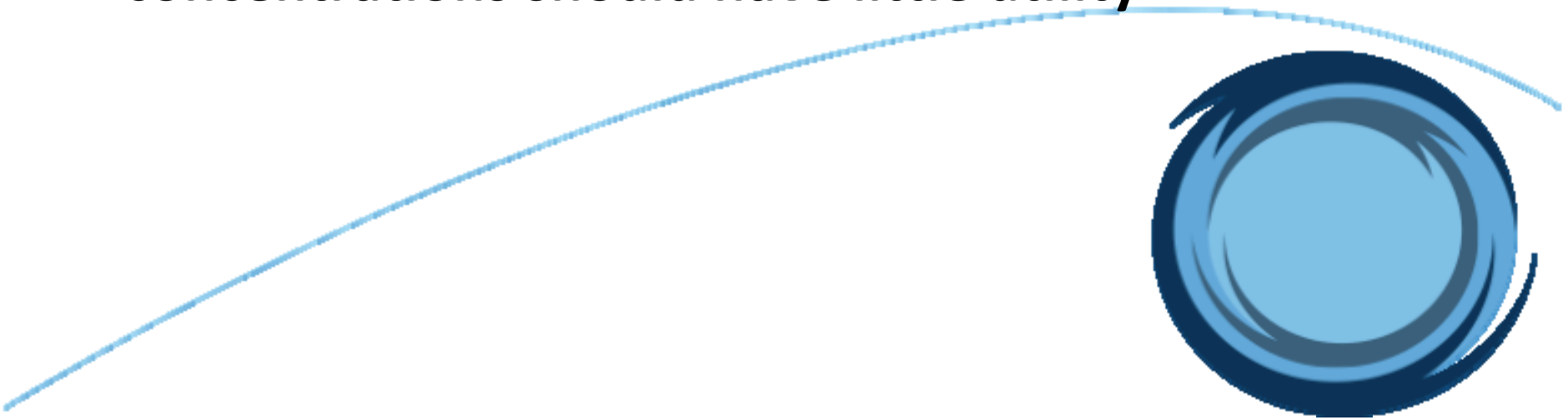
Presentation Is Limited in Scope

Fungal Ecology	Residential Properties	Commercial Properties
Abnormal	Applies	Residence Time Distributions Work
Normal	Doesn't Apply	

My Opinion

- indoor ***contaminant*** spore concentrations are a function of the indoor micro-environment rather than the outdoor macro-climate
- Therefore, comparing indoor to outdoor spore concentrations should have little utility



If Correct, Then Expect

- [1] Little variation in indoor concentrations of contaminant spores by season or geography
- [2] Little association between indoor & outdoor contaminant spore counts

[1] Effects of Season and Geography

- Macintosh, et al. JOEH, 3:379-89 (2006)
- Spore data from EPA BASE* program
- 44 office buildings in 6 of 10 climate zones
  - 6 indoor and 2 outdoor samples
  - Morning and afternoon

*Building Assessment and Survey Evaluation

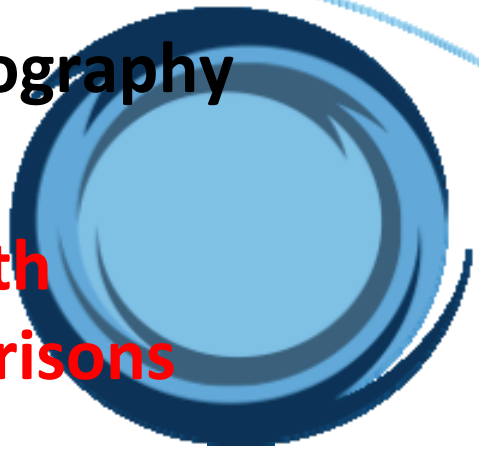
Outdoor Spores [Commercial Buildings]

- **Spore counts did vary significantly**
  - **by season**
  - **by EPA climate zone (geographically)**
  - **with time of day**
    - **(morning greater than afternoon)**

"Significant" means statistically significant

Indoor Spores [Commercial Buildings]

- Spore counts did not vary
  - by season
  - By EPA climate zone (geographically)
  - with time of day
- Conclusion: little effect of season or geography on indoor spore counts
  - Numerous peer-reviewed studies with similar conclusions about I/O comparisons



[2] Association Between Indoor and Outdoor Spores in Contaminated Houses

- **Data provided by Rimkus Consulting Group***
- **108 residential properties**
  - **Criterion: *Asp/Pen* detected**
  - **Broad geographical range**
    - **located in 23 cities in 9 states**
    - **Representing 7 of 10 EPA climate zones**
  - **Collected across seasons - 2-year period**

***Dan Bridge**

108 Residential Projects

- Sample collection: 5-minute Air-O-Cell
- 422 indoor samples
  - Typically 4 indoor samples per project
- 235 outdoor samples
  - Typically 2 outdoor samples , first & last
- Spore types:
  - *Cladosporium* – Dominant Outdoors
  - *Asp/Pen* – Dominant Indoors

[1] Effect of Geography on Indoor *Asp/Pen* Spores

Rimkus Consulting Group

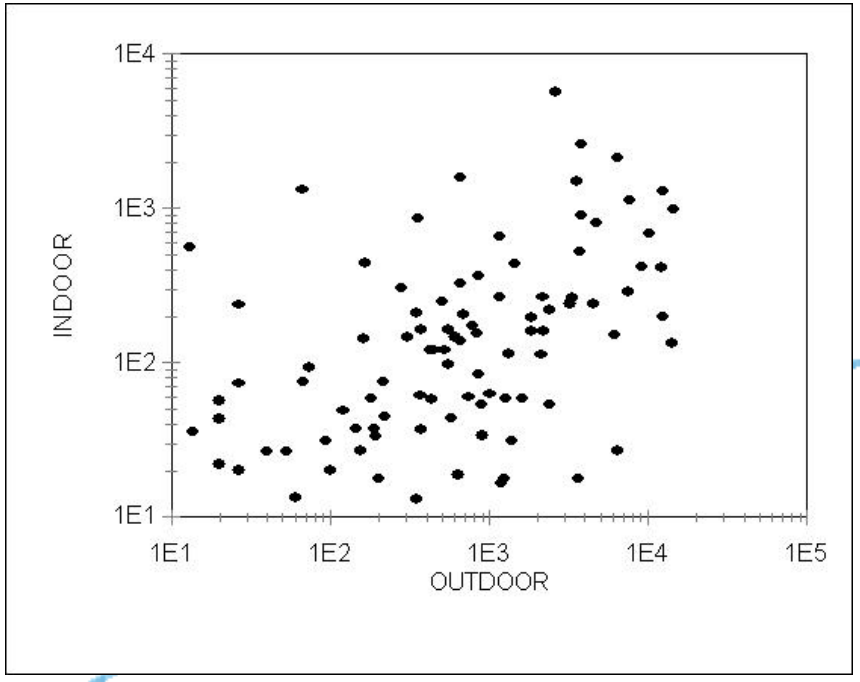
State	N	LCL	Median	UCL
LA	23	90	200	450
AZ	26	80	210	520
GA	34	180	290	480
NV	23	150	365	870
IL	66	270	465	800
TX	89	465	700	2,700
FL	56	370	770	1,600
MD	18	450	1,300	4,000

No statistical difference in Medians for 6 of 8 states: 95 % Confidence Limits

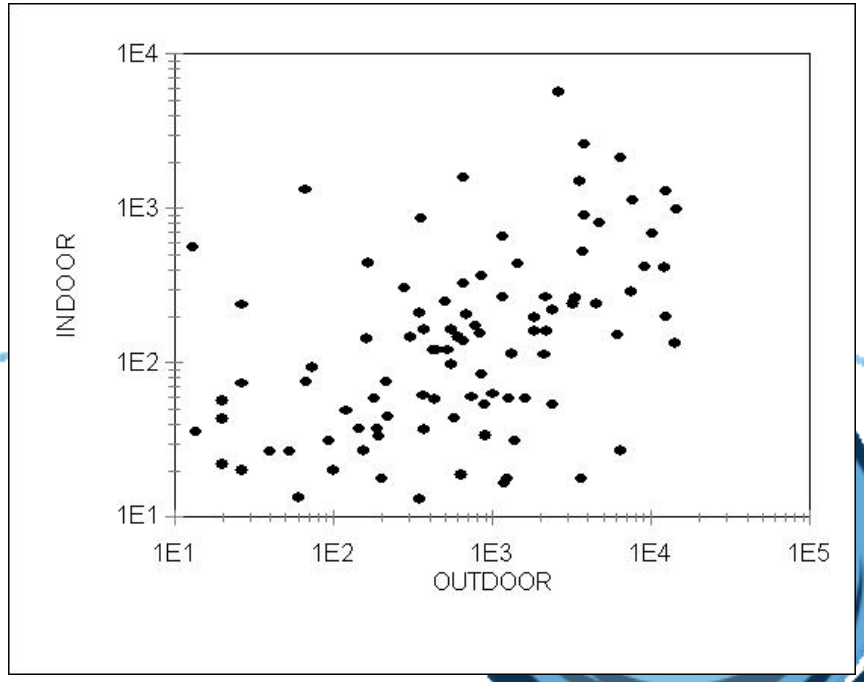
[2] Correlations

Rimkus: Average Concentrations per Project

***Cladosporium*: r = 0.26**



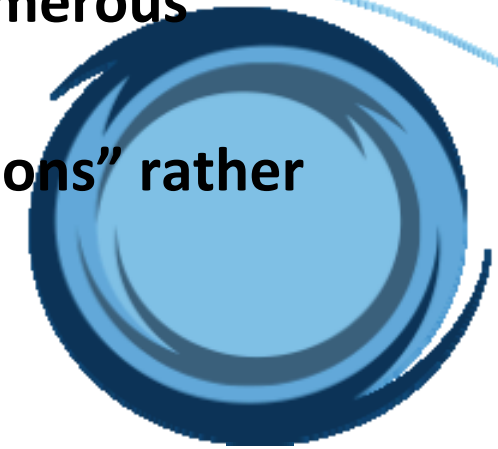
***Asp/Pen*: r = 0.36**



Little correlation between indoor and outdoor spores

Conclusions

- Indoor spores in contaminated houses:
  - Showed little correlation with outdoor spores
  - Showed little variation with season or geography
- Comparing indoor to outdoor spore concentrations:
  - Had little utility in these studies
  - Has been shown to have little utility in numerous other peer-reviewed studies
  - Ignores the utility of comparing “distributions” rather than concentrations



Are There other Approaches to Interpreting Airborne Samples?

Reference Method [Lower Utility]

Compare indoor to outdoor spore concentrations

Control Method [Better Utility]

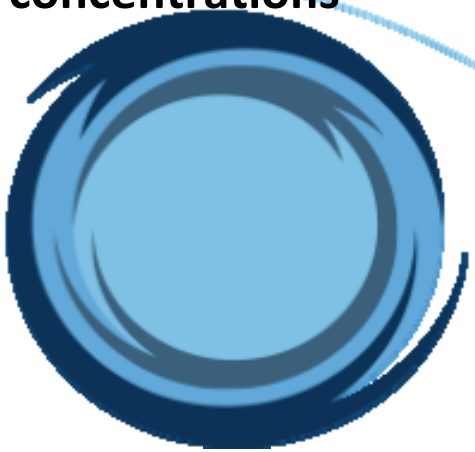
Compare spore concentrations in area A to area B [Similar Exposure Areas]

Database Method [Higher Utility]

Compare spore concentrations to the distribution of concentrations from similar projects

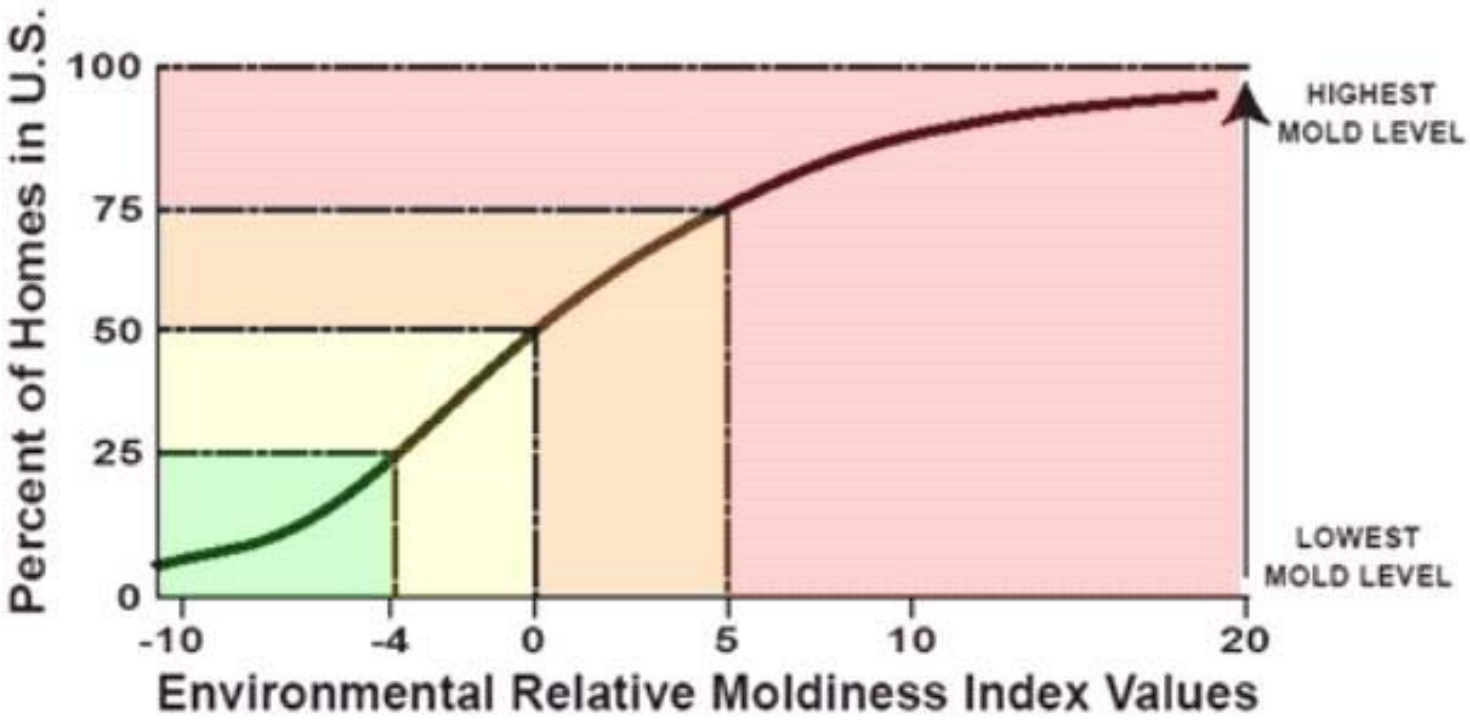
=> Avoids indoor-outdoor comparisons

=> Supports Numerical Guidelines



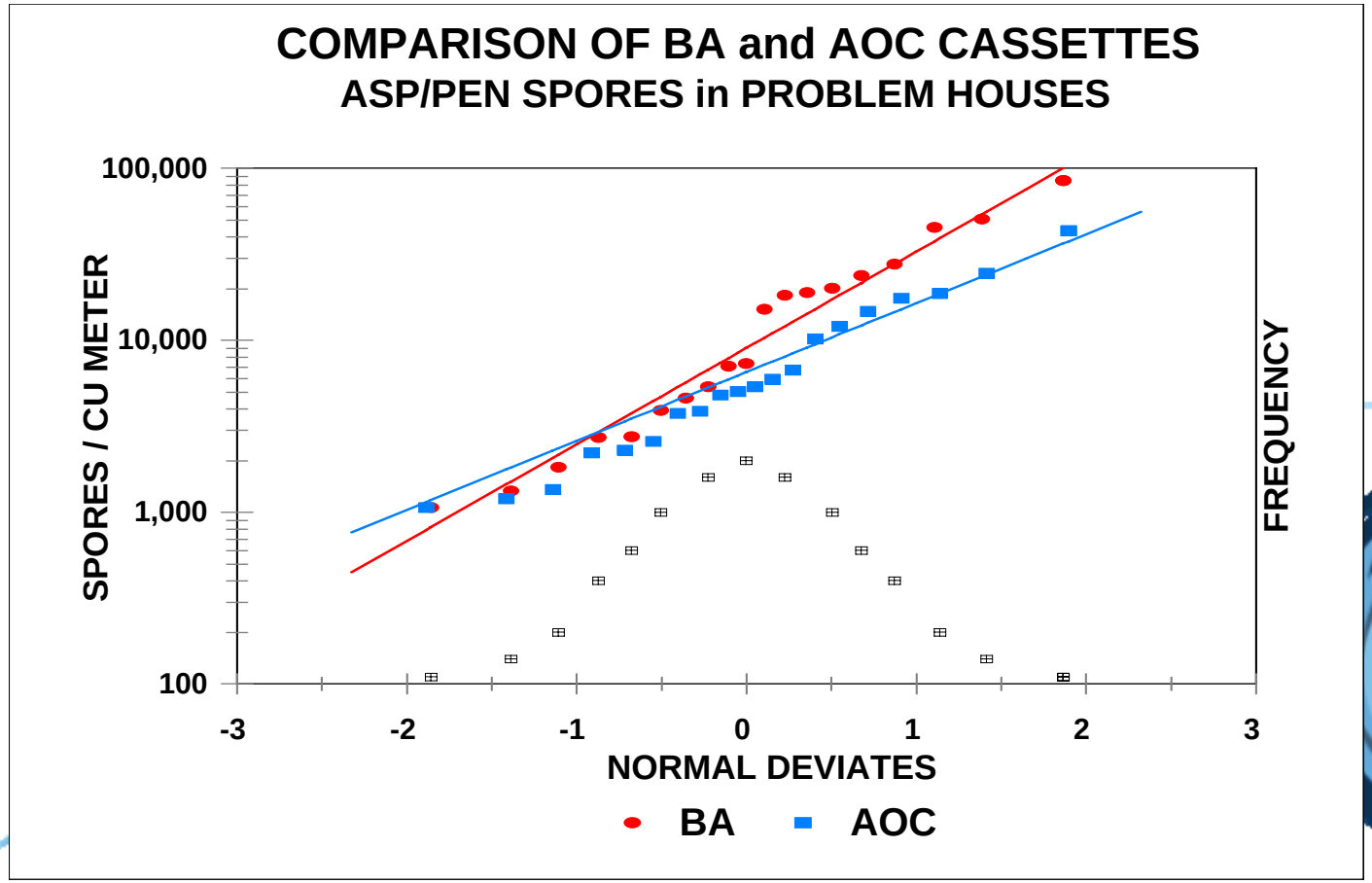
ERMI: Example of A “Database Method with Numerical Guidelines”

Supported by many labs: not controversial



Database Methods

Comparing Distributions, Not Concentrations



Standard Deviation if Mean

Normal Deviation if Median

Study by Baxter et al*

"Database Method with Numerical Guidelines"

- 393 airborne samples collected in 126 residential buildings in CA
- Properties were characterized as "clean", "water stained", or "moldy"

* Baxter, Perkins, McGhee & Seltzer; JOEH, 2:8-18 (2005)

Definition of “Condition”

Assessing The Distribution [Database Method]
No reference to outdoor concentrations

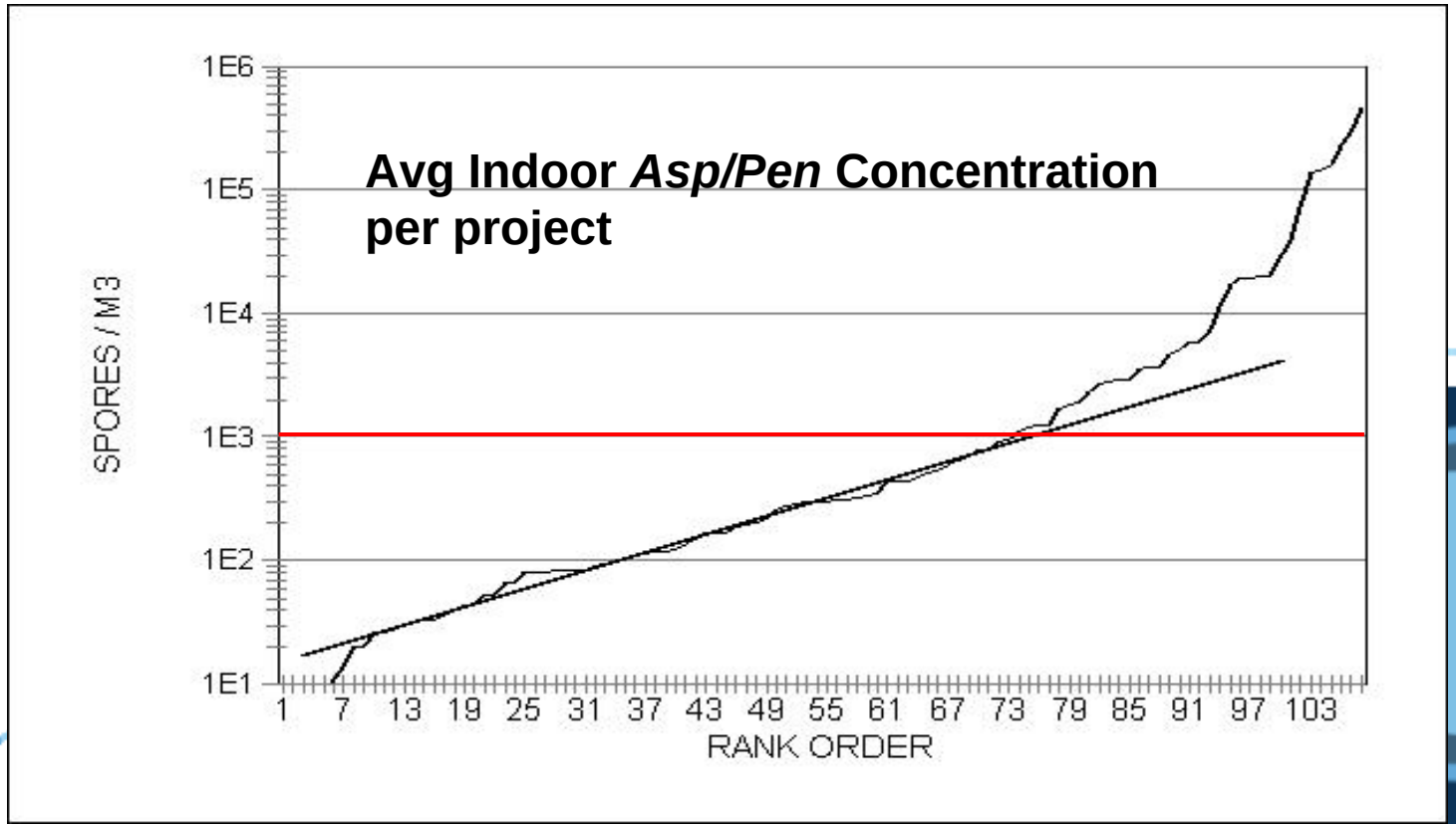
- **“Clean” Buildings**
  - ***Asp/Pen* spores < 750 spores/m^3**
- **“Moldy” Buildings**
  - ***Asp/Pen* spores > 950 spores/m^3**

750 - 950 spores/m^3 => “Professional Judgment”

Baxter et al

Rimkus Consulting Group: Rank Order

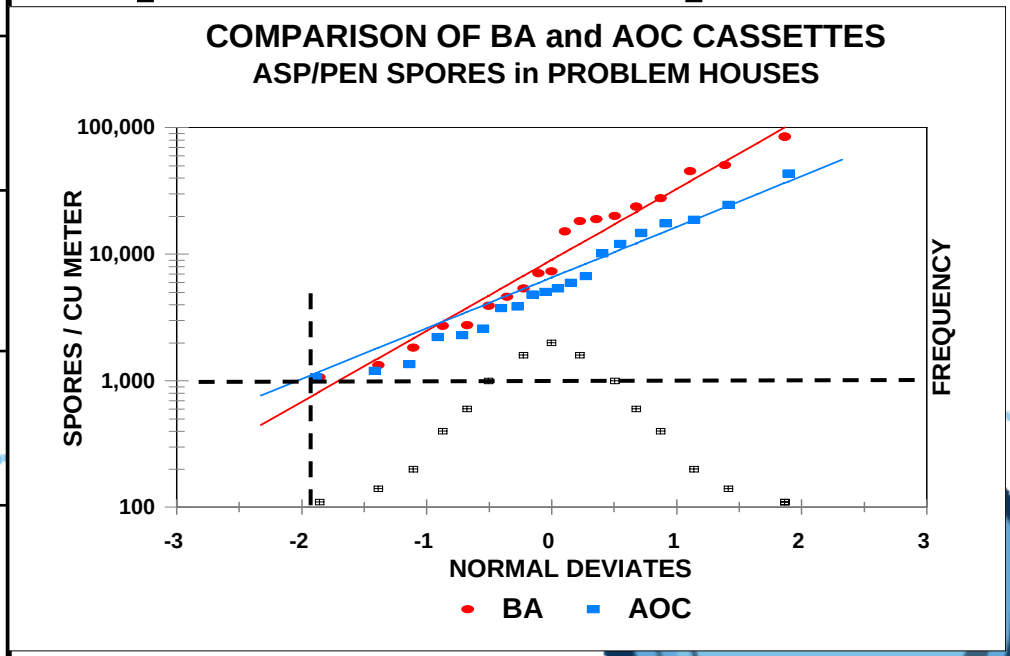
Assessing The Distribution [Database Method]
No reference to outdoor concentrations



Spurgeon Data: *Asp/Pen* Spores

CUMULATIVE %	AOC CASS	FILTER CASS
5 %	1,010	1,080
16 % [-1 ND]	2,000	2,500
50 % [Median]	5,650	9,000
84 % [+1 ND]	16,100	32,600
95 %	31,600	75,000

Comparing Distributions [Database Method]



Only 5 % of samples in problem houses < 1,000 s/m³, & 2,000 s/m³ is -1 ND below the median

Guidelines for “Clean” and “Moldy” Residential Buildings?

“Moldy” by three independent studies:

- **Baxter data: *Asp/Pen* => 950 spores/m^3**
- **Rimkus data: *Asp/Pen* => 1,000 spores/m^3**
- **Spurgeon data: *Asp/Pen* => 1,000-1,100 spores/m^3**

Database methods selected in all three studies – and all with similar numerical guidelines

- coincidence?

Example Numerical Guidelines for “Clean” and “Moldy” Residential Buildings?

***Asp/Pen*: spores/m^3**

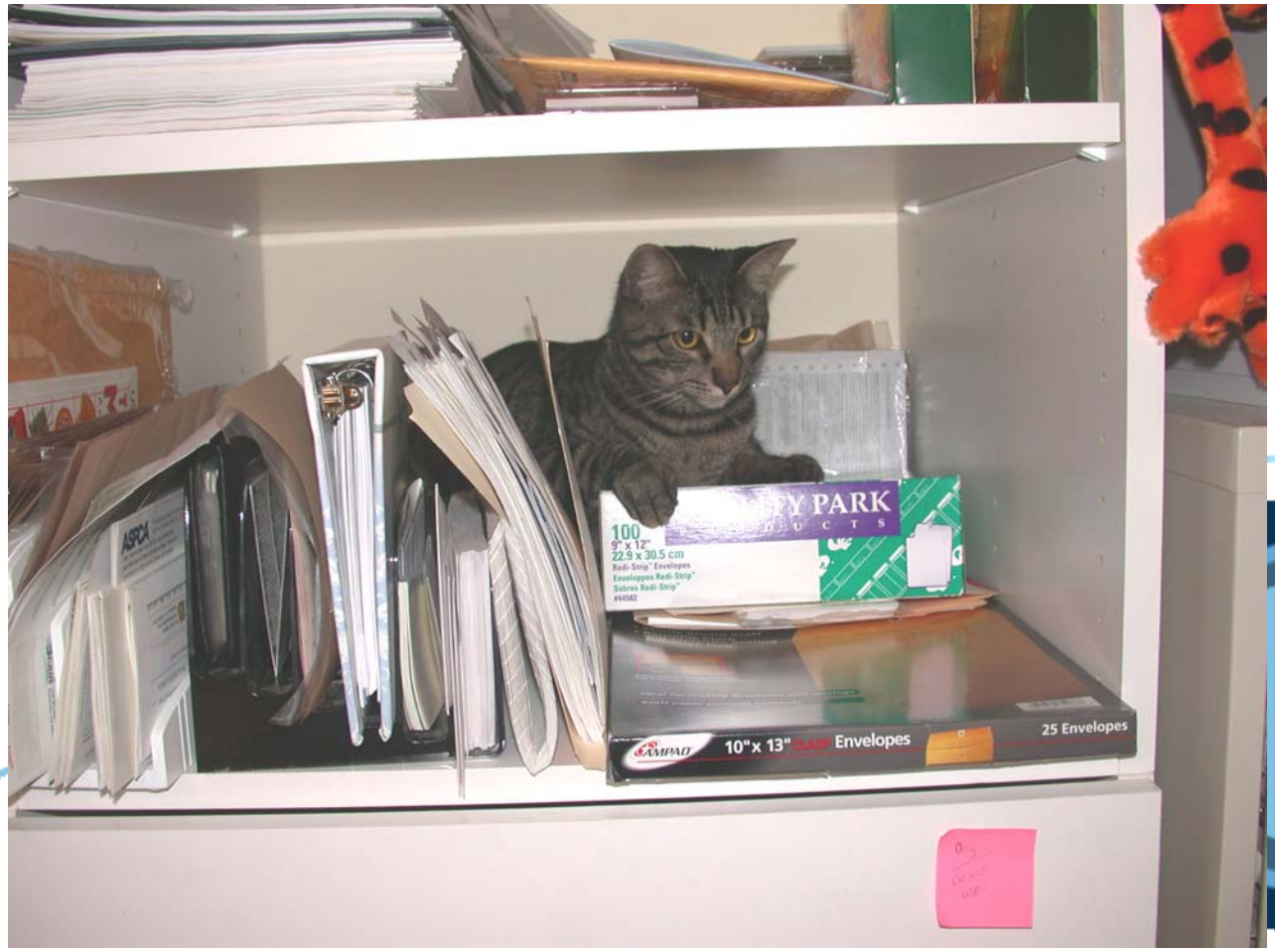
0 – 750: No evidence of contamination

750 – 1,250: Possible evidence of contamination

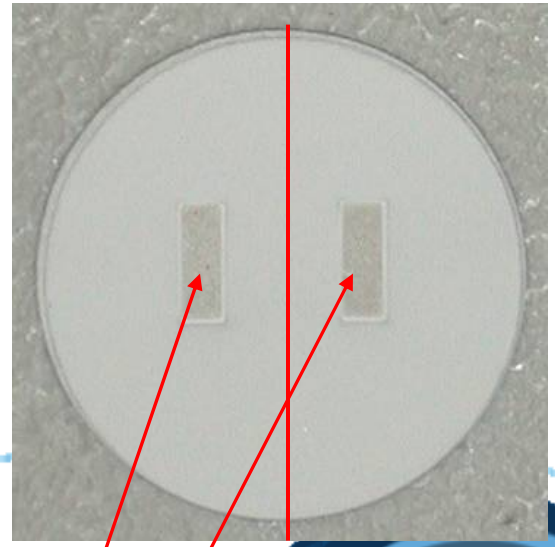
1,250 – 2,000: Probable evidence of contamination

> 2,000: Evidence of contamination

Airborne Samples in Hospitals



Assessing HEPA-Filtered Air in OR's & ICU's



Bi-Air Filter Cassette

Dual sample traces
20-fold concentration

Spore Counts

qPCR or Culture

"Database Method with Numerical Guidelines" in Hospitals

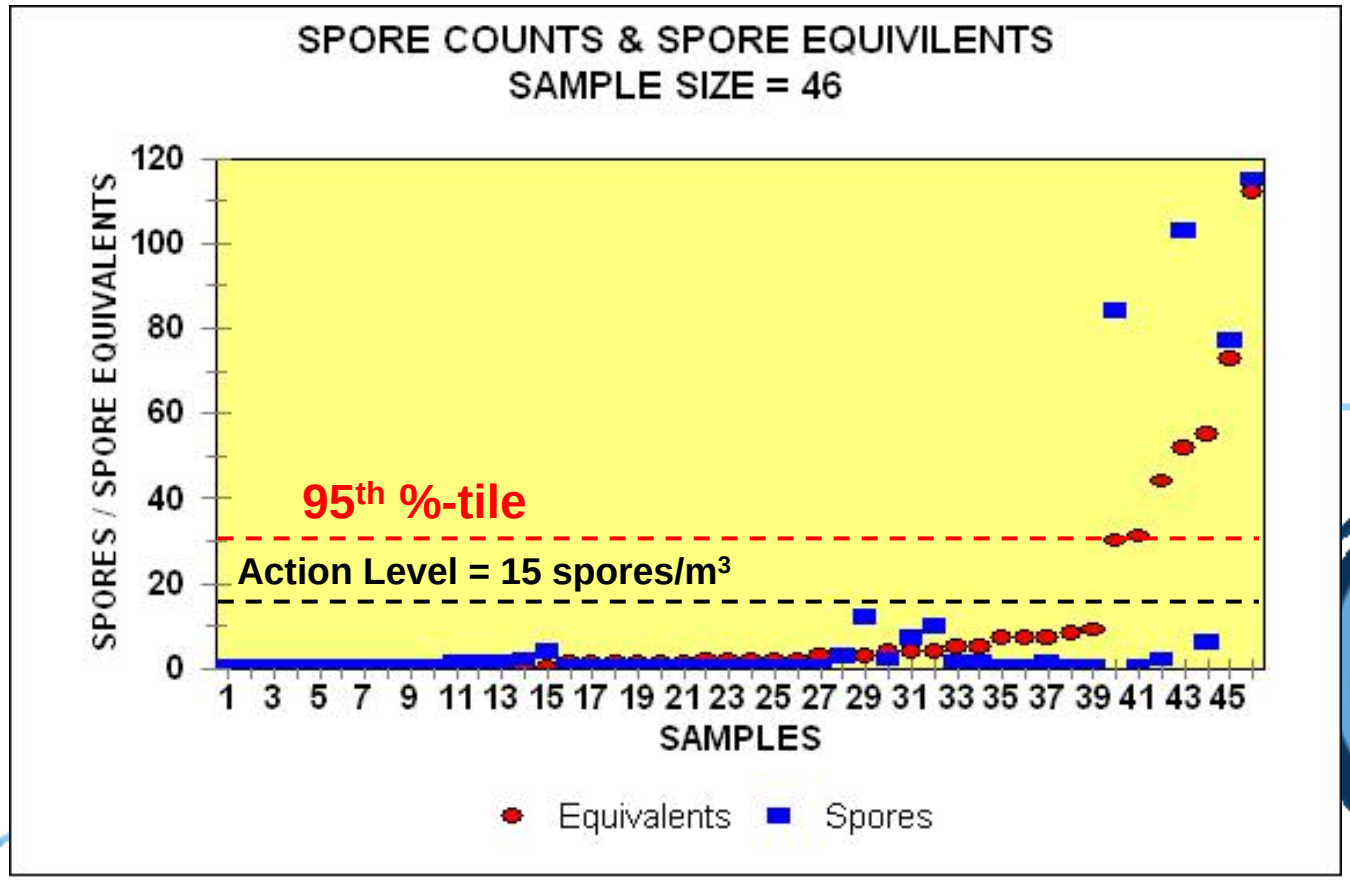
***Asp/Pen* Spores: Triple-filtered Air**

Spores/m^3	OR's	ICU's
Samples [7 hosp]	20	29
Median	2.1	5.2
95th Percentile	6*	30

***25 spores/m^3 of *Asp/Pen* in OR resulted in remediation**

***NO REFERENCE TO OUTDOOR CONCENTRATIONS**

Numerical Guidelines in Hospital ICUs: Database: No Indoor-Outdoor Comparisons



“Database Methods with Numerical Guidelines”

- **Database Methods:**
  - Many laboratories now support ERMI
    - Database method with numerical guidelines
  - Comparing distributions, not concentrations, substantially improves data quality
- **Numerical Guidelines:**
  - Numerical Guidelines for airborne samples is a controversial Issue
  - Maybe it’s time to have an adult conversation about their utility