Differentiating between Clean and Moldy Indoor Environments in Residential Properties

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PO 110, AIHce, Minneapolis, MN

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<table>
<thead>
<tr>
<th>Method</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>Compare Indoor with Outdoor Samples</td>
</tr>
<tr>
<td>Control</td>
<td>Compare results with similar areas or buildings</td>
</tr>
<tr>
<td>Database</td>
<td>Compare results with similar previous samples</td>
</tr>
</tbody>
</table>
Questions Commonly Asked of Us

Are occupants exposed to unusual concentrations of airborne mold?

Is the structure affected by hidden mold?

Are the contents affected by a water intrusion incident?
What We Rarely Ask

Are the data interpretation methods we use valid?
Objective

Compare the Reference, Control, and Database methods for interpreting airborne data collected in residential properties
## Limits of Discussion
[Conclusions May Differ]

<table>
<thead>
<tr>
<th></th>
<th>Residential Properties</th>
<th>Commercial Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Fungal Ecology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abnormal Fungal Ecology</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
The Data
Residential Data: Rimkus Consulting Group

- Database search - 108 residential projects
  - Asp/Pen spores detected indoors
- Projects in 7 of the 10 EPA climate zones
- Included data from 23 cities in 9 states
  - Arizona, California, Florida, Georgia, Illinois, Louisiana, Maryland/DC, Nevada, and Texas

- Samples collected
  - Across seasons over a 2 year period
  - Using 5-minute Air-O-Cell samples
Residential Data:
Rimkus Consulting Group

- **422 indoor samples**
  - Typically 3-5 indoor samples per project
- **235 outdoor samples**
  - 2 outdoor samples per project
  - First & last samples
Data Analyzed

- Dominant spores only
  - *Cladosporium* – dominant outdoors
  - *Asp/Pen* – dominant indoors

- Statistical analysis
  - Average concentration per project
  - Maximum concentration per project
    - Simulated “single sample”
The Results

Similar results for “average” and “maximum” data

Only results for project “averages” presented
Geographical Variation in Indoor *Asp/Pen* Concentrations

<table>
<thead>
<tr>
<th>State</th>
<th>N</th>
<th>LCL</th>
<th>GM</th>
<th>UCL</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA</td>
<td>23</td>
<td>90</td>
<td>200</td>
<td>450</td>
</tr>
<tr>
<td>AZ</td>
<td>26</td>
<td>80</td>
<td>210</td>
<td>520</td>
</tr>
<tr>
<td>GA</td>
<td>34</td>
<td>180</td>
<td>290</td>
<td>480</td>
</tr>
<tr>
<td>NV</td>
<td>23</td>
<td>150</td>
<td>365</td>
<td>870</td>
</tr>
<tr>
<td>IL</td>
<td>66</td>
<td>270</td>
<td>465</td>
<td>800</td>
</tr>
<tr>
<td>TX</td>
<td>89</td>
<td>465</td>
<td>700</td>
<td>2,700</td>
</tr>
<tr>
<td>FL</td>
<td>56</td>
<td>370</td>
<td>770</td>
<td>1,600</td>
</tr>
<tr>
<td>MD</td>
<td>18</td>
<td>450</td>
<td>1,300</td>
<td>4,000</td>
</tr>
</tbody>
</table>
Reference Method

Indoor v. Outdoor

Did the Reference Method have any validity when applied to these 108 projects?
Cladosporium: Indoor v Outdoor for Average Concentrations
**Cladosporium: Indoor v Outdoor**

“Average” project concentrations

- R² = 0.07 [r = 0.26]
- ANOVA: F = 42.9, F_{crit} = 3.9, P = 4 \times 10^{-10}
  - Log transformed data

“Maximum” project concentrations

- R² = 0.09 [r = 0.30]
- ANOVA: F = 27.2, F_{crit} = 3.9, P = 4 \times 10^{-7}

*Indoor v. Outdoor: Little correlation*
Asp/Pen: Indoor v Outdoor for Average Concentrations
Asp/Pen: Indoor v Outdoor

“Average” concentrations

\[ R^2 = 0.13 \quad [r = 0.36] \]

ANOVA: \( F = 25.8, F_{\text{crit}} = 3.9, P = 8 \times 10^{-7} \)

- Log transformed data

“Maximum” concentrations

\[ R^2 = 0.07 \quad [r = 0.26] \]

ANOVA: \( F = 36.9, F_{\text{crit}} = 3.9, P = 5 \times 10^{-9} \)

Indoor v. Outdoor: Little correlation
Conclusion

The most commonly used method of data interpretation, comparing indoor with outdoor samples, had little utility when applied to the 108 residential properties in which contaminant spores were detected.
Options?

- Just take the check and leave
  - The client doesn’t understand it anyway

- Explore the potential utility of the other two data interpretation methods
  - Not as simplistic to apply
  - Require more thought
Control Method

Compares Potentially Contaminated Areas with “Clean” Areas
Characterizing Interior Spaces

AIHA: Similar Exposure Groups
- Members of a SEG have similar exposure potentials
- Should only “average” data within an SEG

Interior areas
- “Similar Exposure Areas” [SEA]
- Areas with similar exposure potentials
- Should only “average” data within an SEA
### Indoor Asp/Pen Concentrations

<table>
<thead>
<tr>
<th>(Sp/m³)</th>
<th>RM 1</th>
<th>RM 2</th>
<th>RM 3</th>
<th>RM 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proj 1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>15,000</td>
</tr>
</tbody>
</table>

An average concentration of 3,800 sp/m³ or two SEA’s?

Data: Rimkus Consulting Group
Indoor *Asp/Pen* Concentrations

Outdoor concentrations not provided
Can we still interpret these data?

<table>
<thead>
<tr>
<th></th>
<th>RM 1</th>
<th>RM 2</th>
<th>RM 3</th>
<th>RM 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proj 2</td>
<td>230</td>
<td>250</td>
<td>870</td>
<td>1,240</td>
</tr>
<tr>
<td>Proj 3</td>
<td>30</td>
<td>90</td>
<td>270</td>
<td>720</td>
</tr>
</tbody>
</table>

Data: Rimkus Consulting Group
Including Outdoor *Asp/Pen*
Concentrations for the 3 projects

<table>
<thead>
<tr>
<th>(Sp/m³)</th>
<th>OUT</th>
<th>RM 1</th>
<th>RM 2</th>
<th>RM 3</th>
<th>RM 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proj 1</td>
<td>0-250</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>15,000</td>
</tr>
<tr>
<td>Proj 2</td>
<td>650-2,300</td>
<td>230</td>
<td>250</td>
<td>870</td>
<td>1,240</td>
</tr>
<tr>
<td>Proj 3</td>
<td>70-350</td>
<td>30</td>
<td>90</td>
<td>270</td>
<td>720</td>
</tr>
</tbody>
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Different interpretation?
Which method is “valid”?

Data: Rimkus Consulting Group
Conclusion

The Control Method did have utility when applied to these residential projects
Database Method

Comparing current sample results with archival data
Database Method

Example: Indoor sample v indoor database

The indoor \textit{Asp/Pen} concentration for a project is at the “90th” percentile for the last “200” indoor samples collected

- Therefore it is an atypical concentration and suggests a potential problem

Not an example: Some laboratories report results referenced to their organizational databases

- Databases composed of outdoor sample results
- Indoor samples compared to outdoor samples
  - Variant of the Reference Method
Baxter et al: Residential Data

Comparison of Baxter & Rimkus Data

Concluded:

- Indoor concentrations of *Asp/Pen* like spores had the most utility in determining whether a building was visibly contaminated with mold.
- Indoor *Asp/Pen* concentrations > 950 spores/m$^3$ were associated with visibly moldy houses.

Rank Order of Average Indoor Asp/Pen Concentrations

Rimkus Consulting Group
Log Plots for “Avg” Asp/Pen

Comparing Avg Airborne Asp/Pen
Range: 100 to 10,000 Spores/m³

Rimkus Consulting Group

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Comparing These Databases

“Moldy” Buildings: *Asp/Pen* Spores

- Baxter: Quartiles > 950 spores/m$^3$
- Rimkus: Rank Order > 1,000 spores/m$^3$
- Rimkus: Log Plot > 300 spores/m$^3$

Based on either database: *Asp/Pen* concentrations in residential properties > 1,000 sp/m$^3$ may be problematic
### If Control Method Doesn’t Work?

<table>
<thead>
<tr>
<th>(Sp/m³)</th>
<th>OUT</th>
<th>RM 1</th>
<th>RM 2</th>
<th>RM 3</th>
<th>RM 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proj 4</td>
<td>0-290</td>
<td>280</td>
<td>310</td>
<td>350</td>
<td>490</td>
</tr>
</tbody>
</table>

Small variation in indoor concentrations
Indoor data similar to outdoor data

- Outdoor *Asp/Pen* = 145;
- Indoor = 360 spores/m³

Data: Rimkus Consulting Group
Then The Database Method

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<thead>
<tr>
<th>(Sp/m³)</th>
<th>OUT</th>
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All rooms “clean”, or all affected by “hidden mold”? 

Rank Order: Problematic if =>1,000 sp/m³

Log Plot: Problematic if => 300 sp/m³

Data: Rimkus Consulting Group
Conclusions

- **Reference Method**: Little or no utility
- **Control Method**: Good utility, often used in commercial buildings
- **Database Method**: Useful supplement for Control Method

Conclusions limited to residential properties with potentially abnormal fungal ecologies
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