

## Detection of Indoor Airborne Fungal Contamination Through Examination of Building Heating, Ventilating and Air Conditioning (HVAC) Filters

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## Overview

- Purpose
- Objectives
- Hypothesis
- Procedure/Methods
- Results
- Conclusions
- Limitations

## Purpose

- This phase
  - To assess viable particle quantification from building HVAC filters as a means of evaluating viable airborne fungal levels
- Overall research
  - To determine whether or not HVAC filter examination can be used as a means of evaluating relative levels of indoor airborne fungal contamination

## Objective

- To compare fungal concentrations detected on building HVAC filters with the results of repeated N-6 impactor sample results

## Hypothesis

- Viable particle quantification results from building HVAC filters are significantly associated with the results of repeated single stage viable impactor sampling performed while the filter is in service

## Procedure

- Conduct regular air sampling with Andersen N-6 viable impactor while filters in place
- Quantify viable particles on filters and compare results to air sampling

## Filter Quantification Procedure\*\*

- Square filter samples (2 – 5 in<sup>2</sup>) cut out manually
- Samples placed in volume of 0.9% sterile saline in Erlenmeyer flask
- Orbital shaker 30 to 60 minutes
- 0.1 mL plated in triplicate onto potato dextrose agar
- Incubated at 20°C for 96 hours
- Colonies (CFU) Counted

\*\* Moritz, M. and H. Martiny: *International Journal of Hygiene and Environmental Medicine [Zentralblatt Fur Hygiene Und Umweltmedizin]*;199:513-526 (1997).

## Filters in Shaking Solution



## What Are We Evaluating?

- Is there a significant relationship between filter quantification results (CFU/m<sup>3</sup>) and air sampling results taken while filter is in service?
  - Regression
- Which method better differentiates viable fungal concentrations in separate areas?
  - ANOVA

## Regression Analysis

- Two Procedures
  - Strength of association between filter quantification (dependent) value and each air sampling concentration (independent) (multiple X for each Y)
  - Strength of association between filter quantification and a single average air concentration value (1 X for each Y)

## Low Volume Systems

- Outpatient Healthcare facility HVAC system decentralized with different zones
  - 5 units and the area they supply involved in research
- 3 Single Family Homes

## High Volume Systems

- Administrative office building
  - One centralized HVAC system with one filter bank
- Academic building containing offices, labs and classrooms
  - Multiple high volume ventilation systems in building. Two units each serving half of two floors involved in research

## Outpatient Facility

- Filters
  - 16" x 25" x 1" or 20" x 25" x 1"
- 3 filter loading periods with air samples taken 2X per week (10 weeks total)
  - 7 week, 2 week, 1 week
- Roof leaks
  - Areas 1 and 5
- Complaints
  - Areas 1, 3 and 5
- Expected order (decreasing fungal levels)
  - 1, (3,5), 2, 4

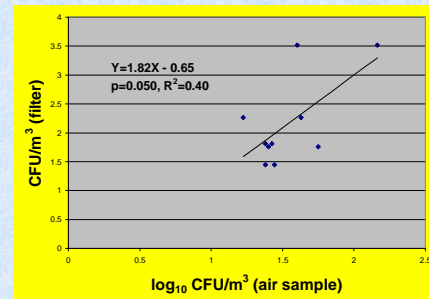
## Summary of Results

Quantification Period / Location	Air sampling mean concentration (CFU/m <sup>3</sup> )	Mean of Log <sub>10</sub> Transformed Air Concentrations	Filter quantification mean detected concentration (CFU/m <sup>3</sup> ) <sup>a</sup>	Air sample/ filter quantification	Filter Coefficient of Variation (σ/mean)
7 week / area 1	69.62	1.75	13	54.88	0.233
7 week / area 2	52.60	1.63	1.07	52.77	0.187
7 week / area 3	51.99	1.58	0.80	57.56	0.341
7 week / area 4	34.99	1.50	1.32	28.25	0.010
7 week / area 5	66.21	1.61	0.96	72.47	0.322
2 week / area 1	134.18	2.04	7.23	18.56	0.237
2 week / area 2	45.54	1.61	2.39	19.05	0.297
2 week / area 3	45.63	1.63	1.02	44.74	0.173
2 week / area 4	34.26	1.50	3.2	10.71	0.299
2 week / area 5	65.21	1.76	2.34	27.87	0.274
1 week / area 1	92.84	1.88	3.52	26.38	0.355
1 week / area 2	25.32	1.40	1.81	13.99	0.229
1 week / area 3	45.47	1.58	1.76	25.84	0.219
1 week / area 4	25.90	1.41	1.45	17.86	0.211
1 week / area 5	29.64	1.43	2.26	13.12	0.230

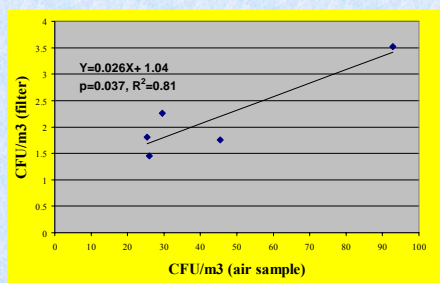
## Outpatient Facility Regression Analysis

Regression	Significant (Y/N)	p-value	R <sup>2</sup>
<b>Log<sub>10</sub> Transformed Analysis</b>			
one week filter vs one week air samples	Y	0.050	0.40
two week filter vs two week air samples	Y	0.024	0.25
seven week filter vs seven week air samples	N	0.788	0.00
<b>Untransformed Analysis</b>			
one week filter vs one week air sampling average	Y	0.037	0.81
two week filter vs two week air sampling average	Y	0.047	0.78
seven week filter vs seven week air sampling average	N	0.786	0.03

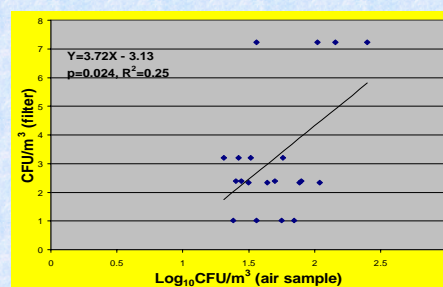
## One Week Filter vs Log<sub>10</sub> One Week Air Sampling Concentrations



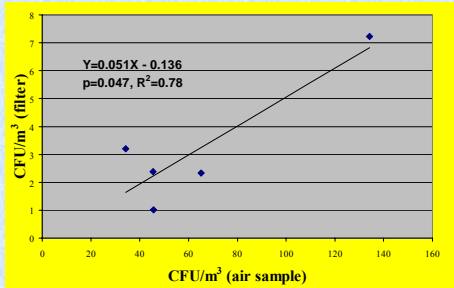
## One Week Filter vs One Week Air Sampling Concentration Average



## Two Week Filter vs Log<sub>10</sub> Two Week Air Sampling Concentrations



### Two Week Filter vs Two Week Air Sampling Concentration Average



### Outpatient ANOVA Groupings

Sample	Significant (Y/N)	P-value	Order (descending)	Grouping
10 week Average Air	Y	0.016	1,5,3,2,4	A: 1 AB: 2,3,5 B: 4
7 week filter	Y	0.0098	4,1,2,5,3	A: 1,4 AB: 2,5 B: 3
7 week air	N	0.495	1,5,2,3,4	A:1,5,2,3,4
2 week filter	Y	<0.0001	1,4,2,5,3	A: 1 B: 4 BC: 2,5 C: 3
2 week air	N	0.074	1,5,3,2,4	A: 1,5,3,2,4
1week filter	Y	0.0001	1,5,2,3,4	A: 1 B: 5,2,3,4
1 week air	N	0.359	1,3,5,4,2	A:1,3,5,4,2

### 3 Homes

- 3 single family homes from Midwestern city
  - Ducted ventilation systems operated continuously during data collection
  - Home 1 owners had minor IAQ concerns
  - Home 2 owners had no IAQ concerns
  - Home 3 owners had serious IAQ concerns
    - Expecting descending order 3, 1, 2
- Sampling over 4 days
- Filtrete 16" x 25" x 1" Micro Allergen Extra Reduction Filter (3M, St. Paul, MN)

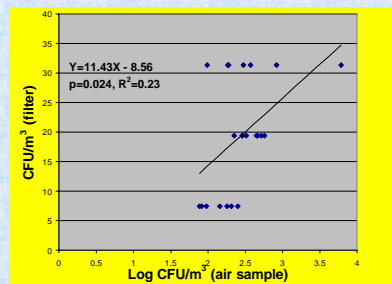
### 3 Homes Summary Results

Home	Filter Quantification (CFU/m <sup>3</sup> )	First Floor Air Sampling Average (CFU/m <sup>3</sup> )	Mean of Log <sub>10</sub> Transformed First Floor Air Concentration	Basement Air Sampling Average (CFU/m <sup>3</sup> )	Mean of Log <sub>10</sub> Transformed Basement Air Concentration	Outdoor Air Sampling Average (CFU/m <sup>3</sup> )	First Floor Air Sample /filter quantification	Filter Coefficient of Variation (σ/mean)
1	19.37	393.73	2.57	386.91	2.54	1188.43	20.33	0.097
2	7.43	148.58	2.13	351.73	2.51	980.40	20.00	0.289
3	31.38	1154.28	2.61	3106.22	3.28	871.88	36.87	0.053

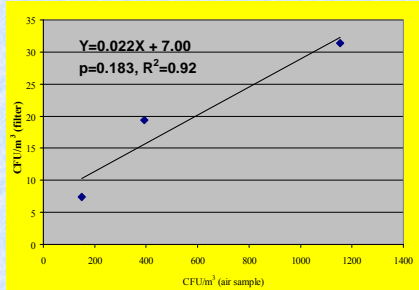
### 3 Home Regression Analysis

Regression	Significant (Y/N)	p-value	R <sup>2</sup>
<b>Log<sub>10</sub> Transformed Analysis</b>			
Filter vs Basement Air	Y	0.0003	0.49
Filter vs First Floor Air	Y	0.024	0.23
Filter vs Outside Air	N	0.604	0.01
<b>Untransformed Analysis</b>			
Filter vs Basement Air Sampling Average	N	0.325	0.76
Filter vs First Floor Air Sampling Average	N	0.182	0.92
Filter vs Outside Air Sampling Average	N	0.780	0.11

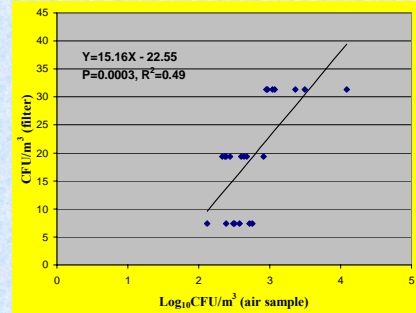
### 3 Home Filter vs Log<sub>10</sub> First Floor Air Sampling Concentrations



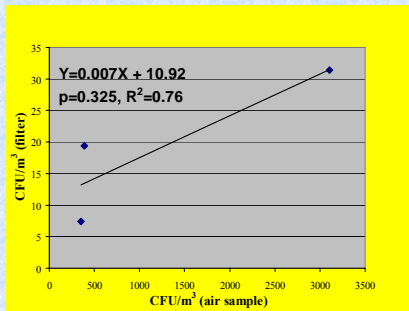
### 3 Home Filter vs First Floor Air Sampling Concentration Average



### 3 Home Filter vs Log<sub>10</sub> Basement Air Sampling Concentrations



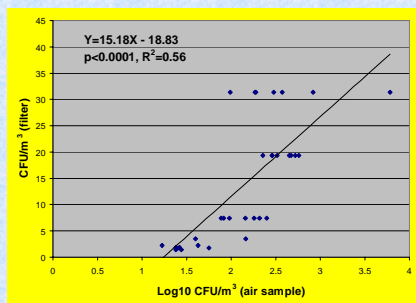
### 3 Home Filter vs Basement Air Sampling Concentration Average



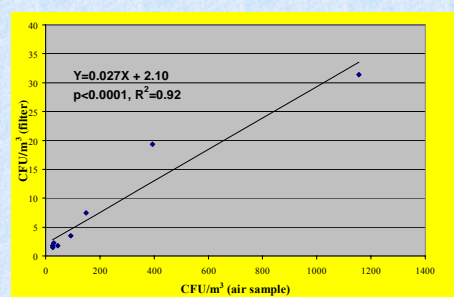
### Three Home ANOVA Groupings

Sample	Significant (Y/N)	p-value	Order (descending)	Grouping
Basement Air	Y	<0.0001	3, 1, 2	A: 3 B: 1,2
First Floor Air	Y	0.039	3, 1, 2	A: 3,1 B: 2
Outdoor Air	N	0.623	1, 3, 2	A: 1, 2, 3
Filter Quantification	Y	<0.0001	3, 1, 2	A: 3 B: 1 C: 2

### One Week Outpatient and First Floor 3 Home Regression (Log<sub>10</sub>)



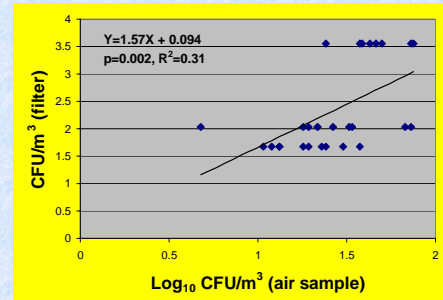
### One Week Outpatient and First Floor 3 Home Regression (Average)



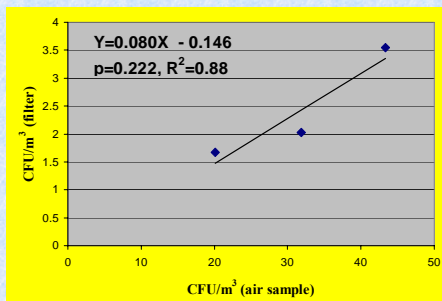
## Combined Administrative and Research Facility Results

Filter Bank	Average Air Sampling Concentration (cfu/m <sup>3</sup> )	Mean of Log <sub>10</sub> Transformed Air Concentrations	Filter Concentration (cfu/m <sup>3</sup> ) <sup>1</sup>	Air sample / filter quantification
research facility west	31.85	1.40	2.03	15.70
research facility east	20.09	1.27	1.67	12.03
Administrative	43.33	1.56	3.55	12.20

## Administrative and Research Facility Combined Regression (Log<sub>10</sub>)



## Administrative and Research Facility Combined Regression (Average)



## Conclusions

- HVAC viable fungal particle filter quantification is a method that has potential for future use in IAQ as a tool to assess relative levels of airborne fungal contamination
- A positive statistically significant relationship exists between filter quantification results and air sampling results taken during filter service
- Viable particle recovery from and quantification of HVAC filters merits further research and development

## Limitations

- Wide variation in types of HVAC systems and filters. Research applicable to a very focused subset.
- Filter collection efficiency
- Relatively short loading periods

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