

# Part 7: Mold Remediation Overview

Friday, August 31

9:10 – 9:45 a.m.

# Mold Remediation Principles

- Physically remove mycelium (growth) from interior surfaces.
- Prevent cross-contamination of occupied or clean areas by mold contamination from areas undergoing remediation.
- Remove settled dusts from zones where mold growth occurred.

## Section 18.1 AIHA (2008) on Performance Criteria

- Plan the mold remediation verification process early in the project.
- An inventory of where mold growth was identified is necessary.
- Someone should independently verify that work practices used by contractors are in accordance with cleanup protocol.

## Mold Remediation Principles (Cont'd)

- Remediation guidelines all recommend increasingly stringent actions to contain dusts as the extent of visible mold growth increases from small scale (a few square feet) to large scale (> 30 to 100 square feet).
- Professional judgment is most important, e.g., if abrasive methods are associated with removal of visible mold, then more conservative containment is needed for dust control.

Practical Use of 3-Step Remediation Metric Strategy to  
Assess Severity of Mold Contamination  
(AIHA, 2008, Chapter 16.3)

- Location of mold in relation to building occupants
- Extent of mold growth
- Resistant/Non-Resistant material

## Mold Growth in AHU/Ductwork

- Consider very close to occupants
- Extent: More than 5M<sup>2</sup>
- Material: Moist dust and dirt; susceptible to mold growth
- “High Severity”

# Mold Growth in Basement Storage Room in University Residence Hall

- Moderately extensive; 3-5M<sup>2</sup>
- Distant from occupied rooms
- Susceptible gypsum board
- “Low Severity”

# Dust Control During Mold Remediation

- Dust suppression methods range from positioning the suction nozzle of a HEPA vacuum at a location where small-scale mold is being removed to depressurized (-5 pa) containments for large removals.
- Other considerations:
  - vibration and abrasion associated with demolition
  - the kind of building
  - susceptible occupants
  - portable containments



# Why Is It Important to Contain Dusts During Mold Remediation?

Rank order taxa of mold spore equivalents (se) in containment during mold remediation and in the outdoor air.

<u>Fungal Taxa</u>	<u>SE/M<sup>3</sup></u>
Outdoor Air on Roof	
Aspergillus niger	2
Aspergillus fumigatus	1
Cladosporium cladosporioides	1
Indoors Within Containment During Wall Removal	
Stachybotrys chartarum	50,000
Penicillium chrysogenum	4,000
Aspergillus sydowii	2,900
Chaetomium globosum	400
Aspergillus versicolor	100

# Why Is It Important to Contain Dusts During Mold Remediation?

Rank Order Taxa of Mold Spores Outdoors and Indoors within Containment Prior to and During Removal of Moldy Wallboard (Spore Trap Analysis)

Fungal Taxa	Spores/M <sup>3</sup>
Outdoor Air on Roof	
Basidiospores	370
Penicillium/Aspergillus	90
Cladosporium	70
Ascospores	55
Indoors in Room Prior to Removal	
Basidiospores	150
Penicillium/Aspergillus	25
Stachybotrys	25
Cladosporium	10
Ascospores	10
Indoors Within Containment During Removal	
Penicillium/Aspergillus	220,000
Stachybotrys	21,500
Cladosporium	12,000
Ascospores	4,500
Basidiospores	4,250

Note: Sampling period 5-10 minutes except for short term (<0.5 minute) samples collected during demolition; n=4-8. Need excellent PPE. From Morey 2011

## Air Sampling for $\beta$ -1,3-D-Glucan When Moldy Moisture-Impervious Vinyl Wallcovering Is Removed from Envelope Wall<sup>a</sup>

Sample Location	$\beta$ -1,3-D-Glucan Concentration (ng/m <sup>3</sup> )
Indoor air; wallcovering undisturbed	0.12
Indoor air; panel of wallcovering removed from wall	13,500.0
Outdoor air	0.03

<sup>a</sup>Polycarbonate filter cassette; analysis according to Rylander et al. Need Excellent PPE. From Morey 2007

# Air Sampling for Molds

- Air sampling for molds with regard to mold remediation:
  - Air sampling is not required in most buildings in order to demonstrate that mold remediation has been effectively carried out.
  - Air sampling is de-emphasized as a quality assurance measure of the effectiveness of mold remediation, especially for small buildings (e.g., most residences) because of the difficulty associated with data interpretation when only a few outdoor and indoor samples are collected. (See AIHA, 2008, Chapter 18)

## How Thorough Was The Diagnostic Inspection For Water And Mold Damage?

“Air sampling for fungal propagules can be a very necessary and important component of final clearance in some buildings in which the initial assessment did not identify all areas of hidden mold growth.”

# HVAC System Mold Remediation

Molds can grow in HVAC systems especially on dirty and porous airstream surfaces such as fiberboard.  
*Cladosporium* species often grow in this niche.

# Microbial Remediation



# Microbial Remediation

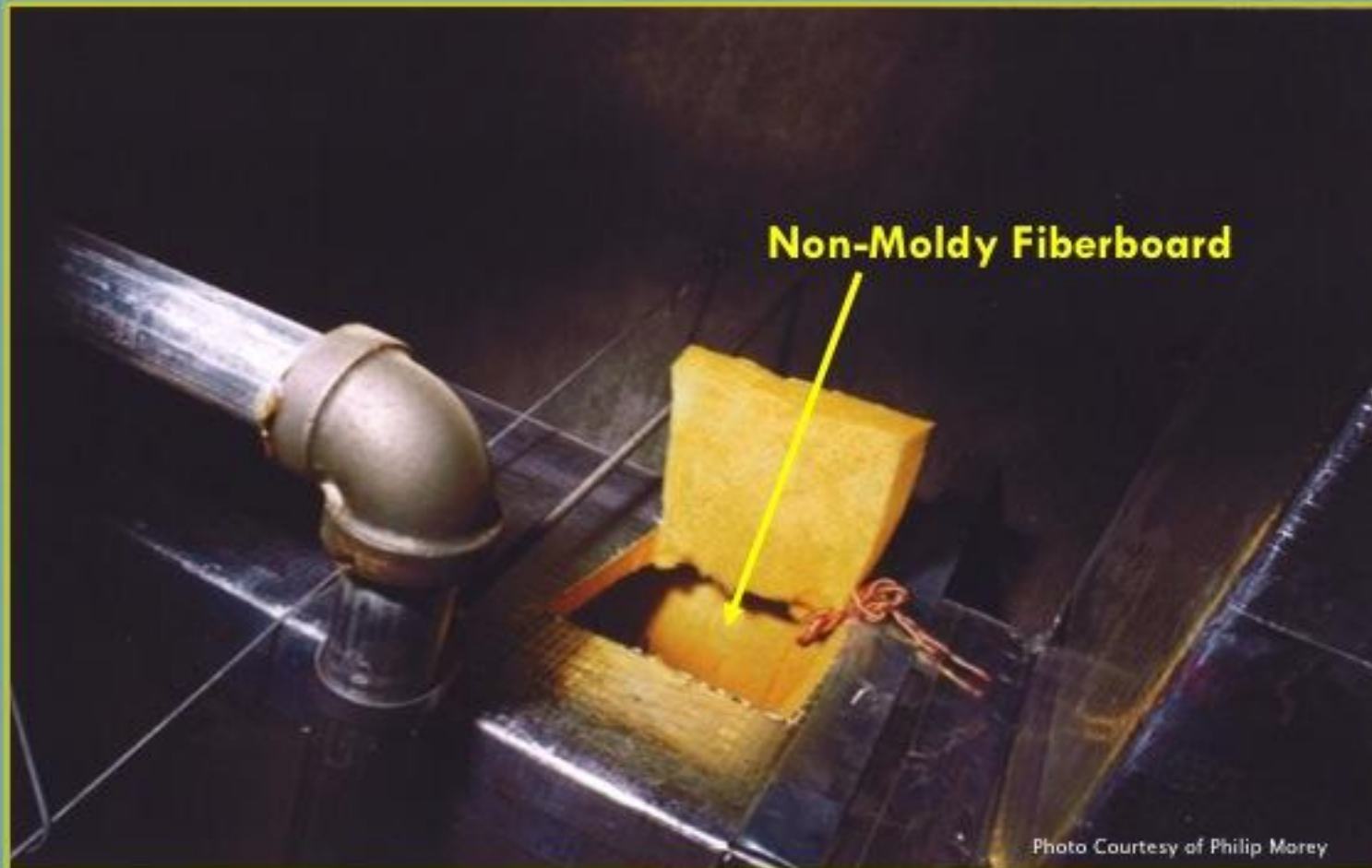


Photo Courtesy of Philip Morey



# HVAC System Mold Remediation

- Moldy HVAC systems should be remediated with great care as AHUs and supply ducts are designed to transport ventilation air to the occupant breathing zone.
- Airstream HVAC surfaces should be smooth, cleanable and resistant to biodeterioration.

# Part 8: Mold Remediation: Sampling Interpretation Difficulties

Friday, August 31  
9:45 – 10:00 a.m.

## Mold Composition in Surface Dusts After Cleanup

- Phylloplane molds are normally present in substantial amounts in dusts from dry, non-moldy buildings.
- However, after mold remediation, water indicator molds (*Asp*, *Pen*, *Chaet.*, etc.) may still be significantly present in the trace amounts of remaining or residual dust. The building has a memory! Dr. Chin Yang.
- Reduce dust levels to lowest feasible amounts (<25 mg/m<sup>2</sup>); AIHA, 2008, Chapter 18.

## Section 18.5.3 AIHA (2008) Microbial Air Sampling As A Component Of Final Clearance

- If air sampling for mold is carried out, there is consensus that data interpretation is best achieved by comparison of indoor rank order taxa with simultaneously collected outdoor taxa.
- A difficulty associated with using air sampling as the primary means of achieving final clearance is the absence of numerical guidelines for airborne fungi and for bioaerosols in general.

# Air Sampling for Molds (Cont'd)

Air Sampling for Culturable Molds as an Indication of Effectiveness of Remediation; AV Is Still Present After Remediation; What Does This Mean?

Location of Samples	Culturable Fungi (CFU/m <sup>3</sup> )			
	Total	AV Only	P/Asp/Eu	C/Alt/Epi
<del>Before remediation</del>				
Floor 1 (N = 10)	650	140	560	45
Floor 2 (N = 20)	120	6	60	30
After remediation				
Floor 1 (N = 20)	450	4	75	300
Floor 2 (N = 30)	730	2	120	400
<del>Morey, 2001, Chapter 4.4; See also Morey, 2007, Chapter 12. How Would You Interpret This Data?</del>				

# Rank Order Taxa Concentrations of Culturable Fungi Indoors and Outdoors After Mold Remediation

Fungal Taxa	Average Conc. (CFU/M <sup>3</sup> )
<u>Outdoor Air on Roof</u>	
<i>Cladosporium cladosporioides</i>	15
<i>Curvularia lunata</i>	11
<i>Penicillium implicatum</i>	5
<i>Penicillium brevicompactum</i>	3
<i>Aspergillus fumigatus</i>	3
<i>Drechslera hawaiiensis</i>	2
<i>Aspergillus japonicus</i>	2
<u>Outdoor Air at Grade Level</u>	
<i>Penicillium brevicompactum</i>	36
<i>Curvularia lunata</i>	18
<i>Alternaria alternata</i>	8
<i>Penicillium implicatum</i>	7
<i>Aspergillus alliaceus</i>	4
<i>Aspergillus japonicus</i>	3
<i>Emericella rugulosa</i>	3
<u>Indoor Air in Formerly Moldy Rooms</u>	
<i>Emericella rugulosa</i>	5
<i>Cladosporium cladosporioides</i>	2
<i>Cladosporium sphaerospermum</i>	2
<i>Penicillium citreonigum</i>	2
<i>Curvularia lunata</i>	2
<i>Penicillium sclerotiorum</i>	1
<i>Penicillium brevicompactum</i>	1

Note: n = 4 for outdoor air; n = 7 indoor air. Laboratory #2 accredited by the American Industrial Hygiene Association, Environmental Microbiology Proficiency Analytical Testing Program; culture conditions: Malt extract agar; culture plate impactor operating at a flow rate of about 0.2m<sup>3</sup>/minute. From Morey 2011

## Rank Order of Mould Taxa Detected in a Two-Year-Old Dust Sample Determined by Different Analytical Methods.

PCR Analysis	
<i>Stachybotrys chartarum</i>	81%
<i>Penicillium raquefortii</i>	3%
<i>Cladosporium cladosporioides</i>	2.5%
<i>Eurotium amstelodami</i>	2.5%
<i>Aspergillus fumigatus</i>	2.5%
<i>Alternaria alternata</i>	2.5%

Dilution Plating on CMA	
<i>Penicillium spp.</i>	70%
<i>Stachybotrys chartarum</i>	20%
<i>Aspergillus niger</i>	10%

Direct Plating on CMA	
<i>Penicillium spp.</i>	50%
<i>Ulocladium botrytis</i>	20%
<i>Stachybotrys chartarum</i>	10%
<i>Chaetomium globosum</i>	10%
<i>Acrodontium spp.</i>	10%

PCR, polymerase chain reaction; CMA, cornmeal agar. Dust sample was sieved and homogenized in the laboratory and aliquots of sample were processed separately by PCR, direct plating and dilution plating methods. Morey 2011

## Analysis Of Dust From Porous Surfaces By PCR Where Contact Sampling Is Not Practical; What Does This Data Mean? How Do You Prove That Porous Contents Are Clean?

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Fungal Taxa in Dust	Spore Equivalents per Milligram
<i>Cladosporium</i> and <i>Alternaria</i> species	35,000
<i>Penicillium</i> and <i>Aspergillus</i> species	11,000
<i>Memmoniella</i> and <i>Stachybotrys</i>	5

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From Morey, 2007



**Part 9: Mold Remediation:  
What Happened**

**Friday, August 31  
10:15 – 10:45 a.m.**

## Mold Remediation: Envelope Was Removed Including Stucco, Building Paper, Gypsum Board And Metal Framing



Rusted metal framing and sill plate in a new building

## Mold Remediation: EIFS, Windows, and Wood Framing Were Removed



Photo Courtesy of Phillip Morey

Framing mold in a window assembly in a new building



Photo Courtesy of Philip Morey

The fine dust and oily film on the metal surface of the fan motor in this undermaintained air-handling unit provide nutrients for the growth of mold which is visible on the fan housing.

Mold Remediation: Recommendation: Remove Superficial  
Mold By Sanding And Fix Crawlspace Moisture Problem.  
Instead: Wood Framing Replaced



Photo Courtesy of Philip Morey

RH in crawl space 75 to 95%; Note mold growth on OSB

Mold Remediation: Fire proofing should have been dried in 28 days; this did not occur; mold growth became visible; moldy fire proofing was replaced with new fire proofing



Fireproofing that is applied wet to structural surfaces must be allowed to dry within the time frame recommended by the manufacturer

## Mold Remediation: Upgrade Preventive Maintenance. Probably Hopeless.



Photo Courtesy of Philip Morey

Maintenance is infrequent because of budget limitations and because of the many FCUs involved. An HVAC design with a few large air handling units may have been a better fit for a limited budget.

## Maintenance Problem After Construction



Standing water is present in the drain pan; the air velocity over the pan is elevated so that downstream surfaces are being wetted



# Part 10: Quality Assurance

Friday, August 31

10:45 – 11:00 a.m.

# Quality Assurance During Mold Remediation

- Quality assurance for mold remediation (AIHA 2001 Microbial Task Force key indicators):
  - Document that appropriate methodologies or protocols were followed.
  - Document that appropriate dust suppression, containment and depressurization techniques were followed.
  - Document that surfaces in remediated spaces were HEPA vacuumed.

## Verification That Mold Remediation Was Effectively Carried Out; At The Completion of Mold Remediation Process

- Was all the visible mold removed? Cellotape Sampling! Carry a small microscope.
- Was all dust and debris removed? White/Black Glove Test!

## All Visually Moldy Materials Have Been Removed



Photo Courtesy of Philip Morey

This is now a normal construction site.

## Quality Assurance (Cont'd)

- Residual dust as a quality assurance key indicator following HEPA vacuum cleaning:

Material Surface	Residual Dust (mg/m <sup>2</sup> )
Nonporous wood bookshelves (cleaning satisfactory)	0.5
Nonporous hardwood flooring (cleaning satisfactory)	7.2
Semi porous concrete block with partially painted surface (cleaning satisfactory)	13
Nonporous floor tile with semi porous grouting (cleaning satisfactory)	67

Morey, 2007, Chapter 12

# Pros and Cons on Measurement of Settled Dust as a Mold Remediation QA Indicator

(AIHA 2008, Section 18)

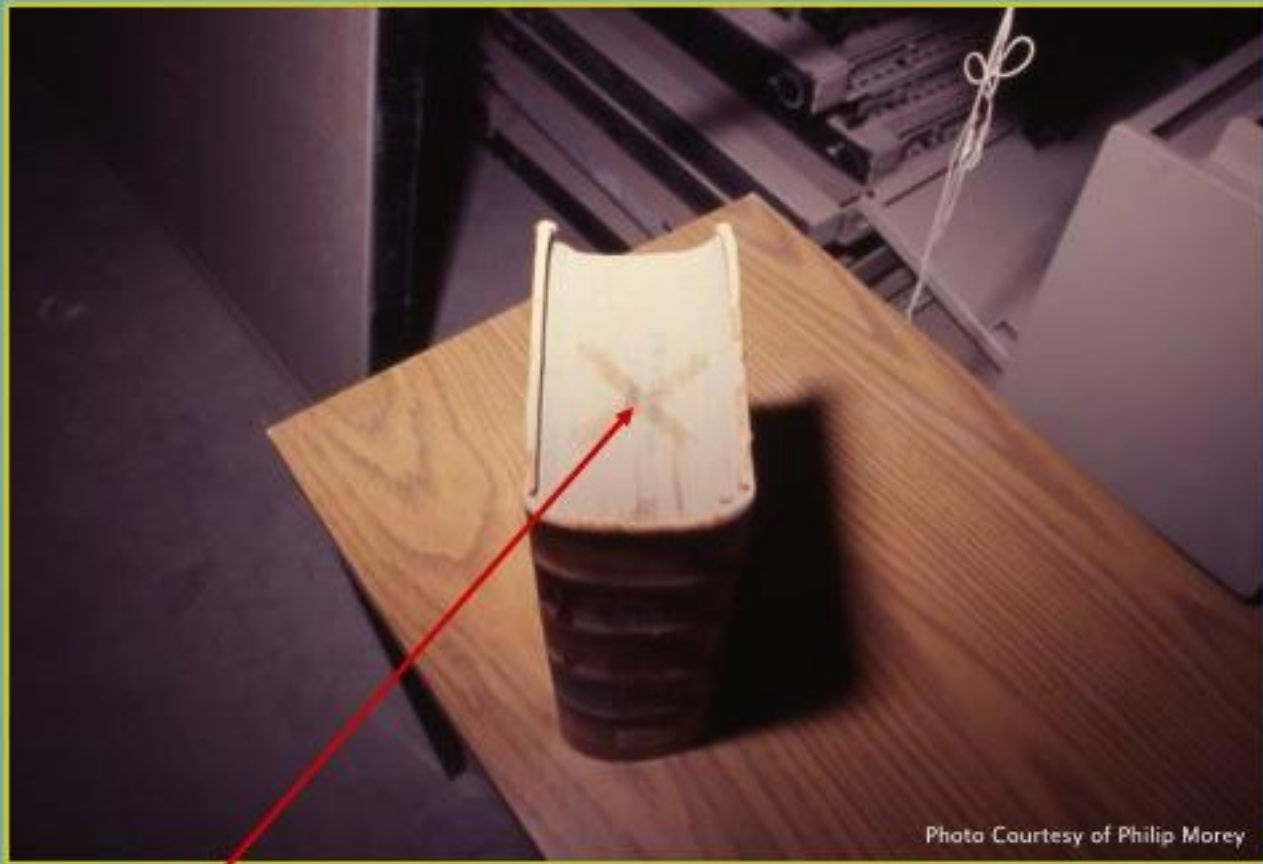
- Does not apply to porous surfaces; does not indicate microbial composition of the dust.
- This performance criterion is understandable and reasonable by contractor; performance criteria based on mycological analysis is often confusing to contractor.

# Successful Mold Remediation



**Almost no residual dust on nonporous surfaces.**

# Unsuccessful Mold Remediation



**Considerable residual dust on porous surfaces.**



## Tapelift Sample: Mycelium is still present



Photo Courtesy of Philip Morey

Does inspector fail the remediator because of the presence of one centimeter of microscopic mold growth?

## Interpretation of Tapelift Sampling During Final Clearance

- The presence of mycelium or conidiophores in a single tapelift sample implies that only 1-2cm<sup>2</sup> of material surface is un-remediated, and only small-scale subsequent cleaning actions are warranted.
- The occurrence of mycelia and conidiophores in many areas across a material surface shows that remediation was unsuccessful, and a large-scale re-cleaning effort is still needed.

## Final Cleaning And Any Sampling That Is Carried Out At Or Just After Final Cleaning

- Some Mold Spores Are Normally Present On Interior Surfaces Including Remediated Surfaces (Inst. Medicine, Pp. 300, 2004)
- So Are We Trying To Remove The Last Spore?

## Failure of HEPA Filtration in Vacuum Cleaners and AFDs Used in Mold Remediation

- Some mold remediation contractors rely on a certificate from the manufacturer to demonstrate that their equipment is 99.97% effective in removing 0.3 micrometer particles.
- Should you test the exhaust air being discharged through the HEPA filter?

## Testing the Filtration Efficiency of a HEPA Vacuum Cleaner With A Direct-Reading Airborne Particle Meter

PARTICLE SIZE MICROMETERS	BACKGROUND (NO VACUUM)	TURN VACUUM ON; HEPA EXHAUST AIR	VACUUM DUSTY SURFACES; HEPA EXHAUST AIR
0.5	3940	2800	9600
0.7	2100	1100	3500
1.0	1150	500	1500
2.0	500	250	500
5.0	50	50	40
10.0	10	20	6

Exhaust air from HEPA vacuum should have zero or near zero count of particles of all above sizes.

## Final Verification That Mold Remediation Was Properly Carried Out

- Depend mostly on physical inspection; white/black glove test; cellotape sampling; carry a microscope
- Air sampling may be useful for hidden mold; Culture analysis of surface dust and debris and cellotape testing may be useful in some buildings

## Primary Objective of Mold Remediation

“The primary objective of mold remediation, based on guidelines published between 1993 and 2004, is to remove visible mold growth and return material surfaces to a satisfactory condition.” (AIHA, 2008, Section 18, pp. 219)