

Spore Migration in the Indoor Environment

AIHCE 2007

Roundtable 202

Gary N. Crawford, CIH

Boelter Associates, Inc.

Park Ridge, IL

Visible & Hidden Mold

- Visible Mold¹
 - Colonized a substrate
 - Formed fungal mycelia
 - Sufficiently developed to be visible to the naked eye
 - May be active, dormant or non-viable
- Micro-colonies, need microscope to see colonies.

Visible & Hidden Mold

- Hidden Mold¹
 - Visible mold growth within a building
 - Concealed from view during normal walk thru inspection
 - May be in/on structural, mechanical, or electrical systems or finishes, furnishings, or fixtures
 - May be in HVAC system or building cavities
 - May be active, dormant or non-viable

Mold Exposures

- Primarily inhalation
- Skin contact
- Ingestion

Inhalation Exposure Mechanisms

- Source – visible or hidden mold
- Pathway – route between source and receptor
- Driving force – energies that transport bioaerosols thru the pathway
- **Source + Pathway + Driving force = Exposure [when receptor is present]**

Structural Mold Sources

- Wall cavities
- Wall sheathing
- Attics
- Crawl spaces
- Ceiling interstitial spaces
- Basements
- Other exposed and hidden surfaces



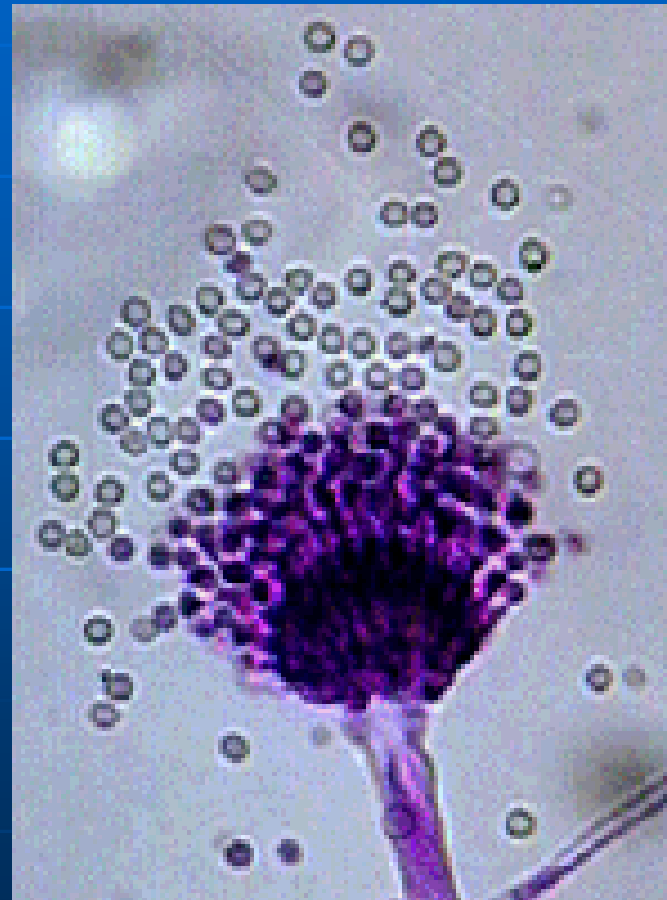
HVAC/Mechanical Systems

- Mold sources
 - Condensate collection areas
 - Cooling coil housing insulation
 - Duct liners
 - Pipe insulation
 - Duct coverings



Air Dispersal

- Mold Spores –
 - Most “Born to Fly”
- Predominant method of spore dissemination in fungal reproduction



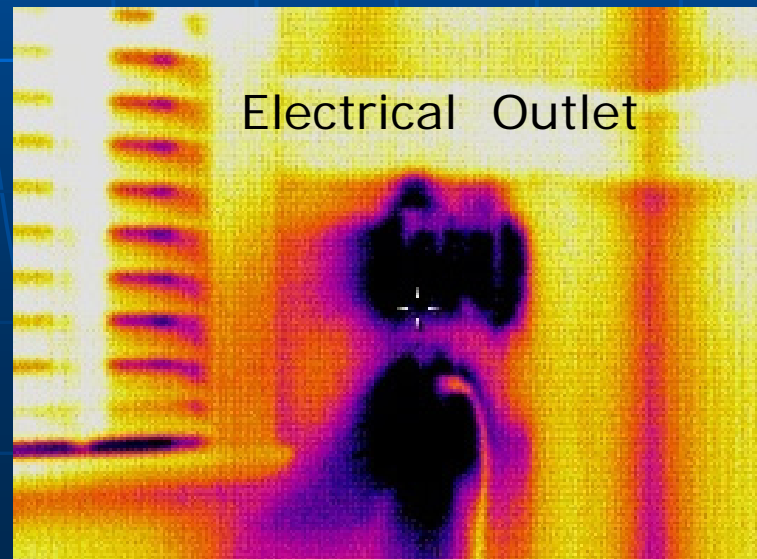
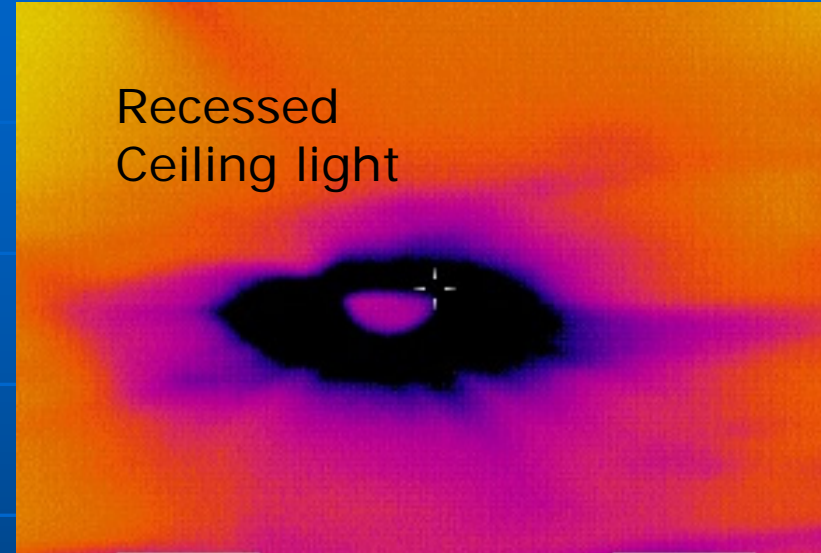
Other Dispersal

- Water – leaks and flow can transport spores to new locations
- Insects/animals – contact with mold colony can transport spores

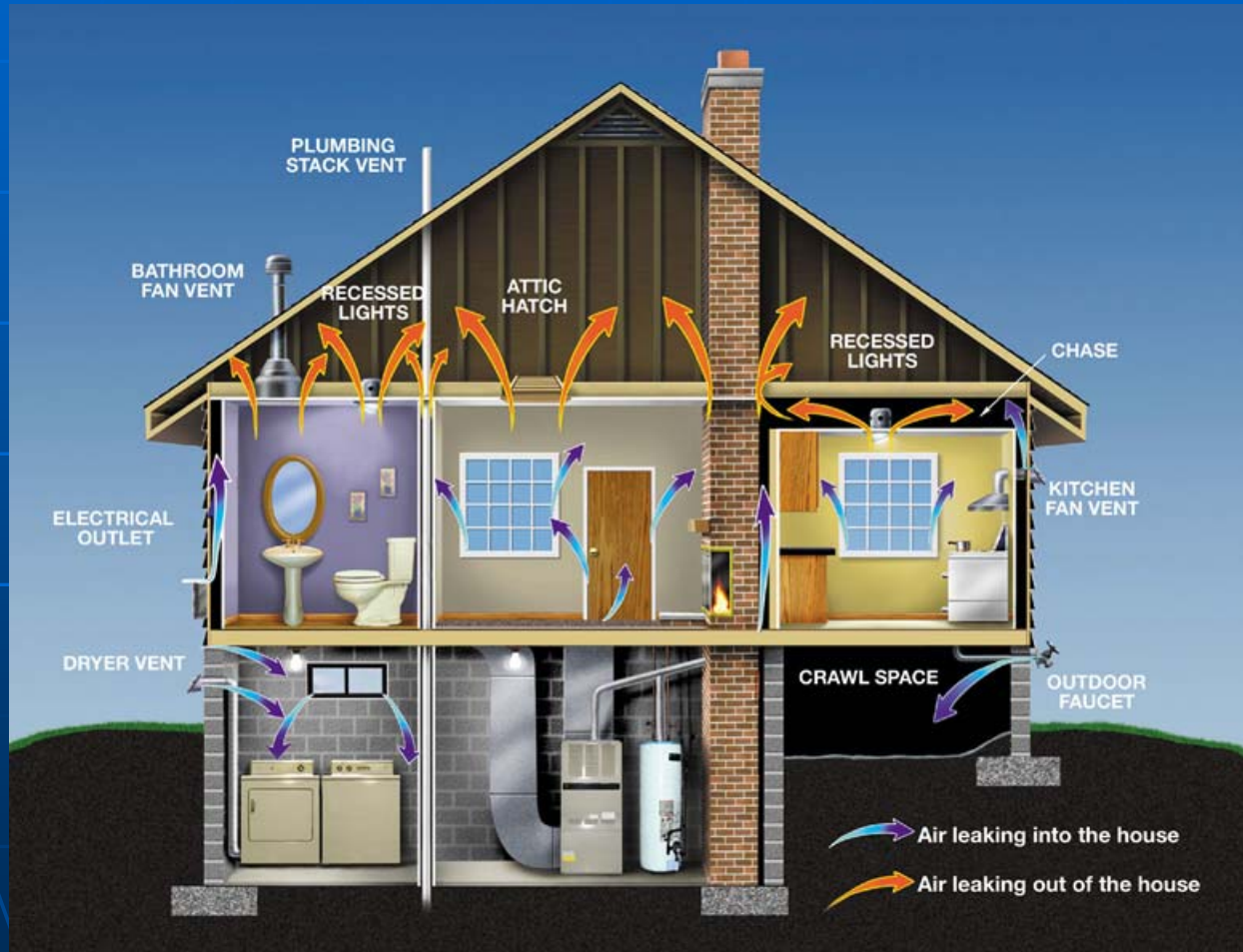
Common Building Pathways

- Chases
- Interstitial spaces
- Conduit & Pipes
- Gaps around plumbing & electrical fixtures
- Cracks and gaps in walls, floors, ceilings
- Unsealed wall penetrations
- Construction joints
- Window frame assemblies (even good windows can leak 0.3 cfm/sq.ft.!))

Building Envelope Pathways



Air Movement Pathways



Air Infiltration Rates

- Tightly constructed homes = 0.25 to 0.35 ACH.
 - A typically built newer home = about 1.75 ACH.
 - Older poorly weather-stripped and sealed homes may be >2.5 ACH.
- A 2500 sq. ft. home with 8 ft ceilings = about 20,000 cu. ft of air.
 - Between 5,000 and 50,000 cu. ft. of air per hour would be expected to move through that home due to infiltration.

Air Infiltration Pathways

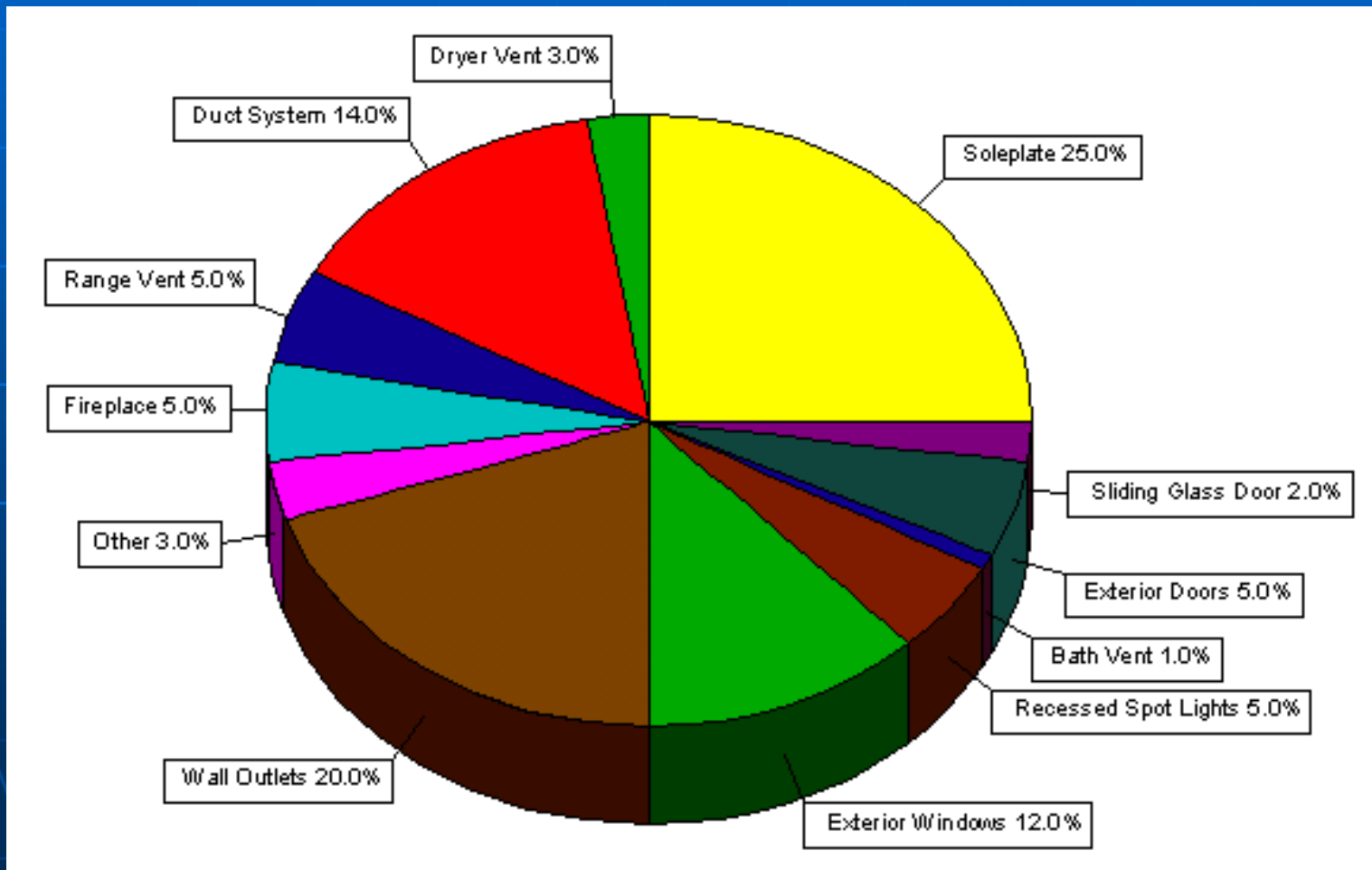
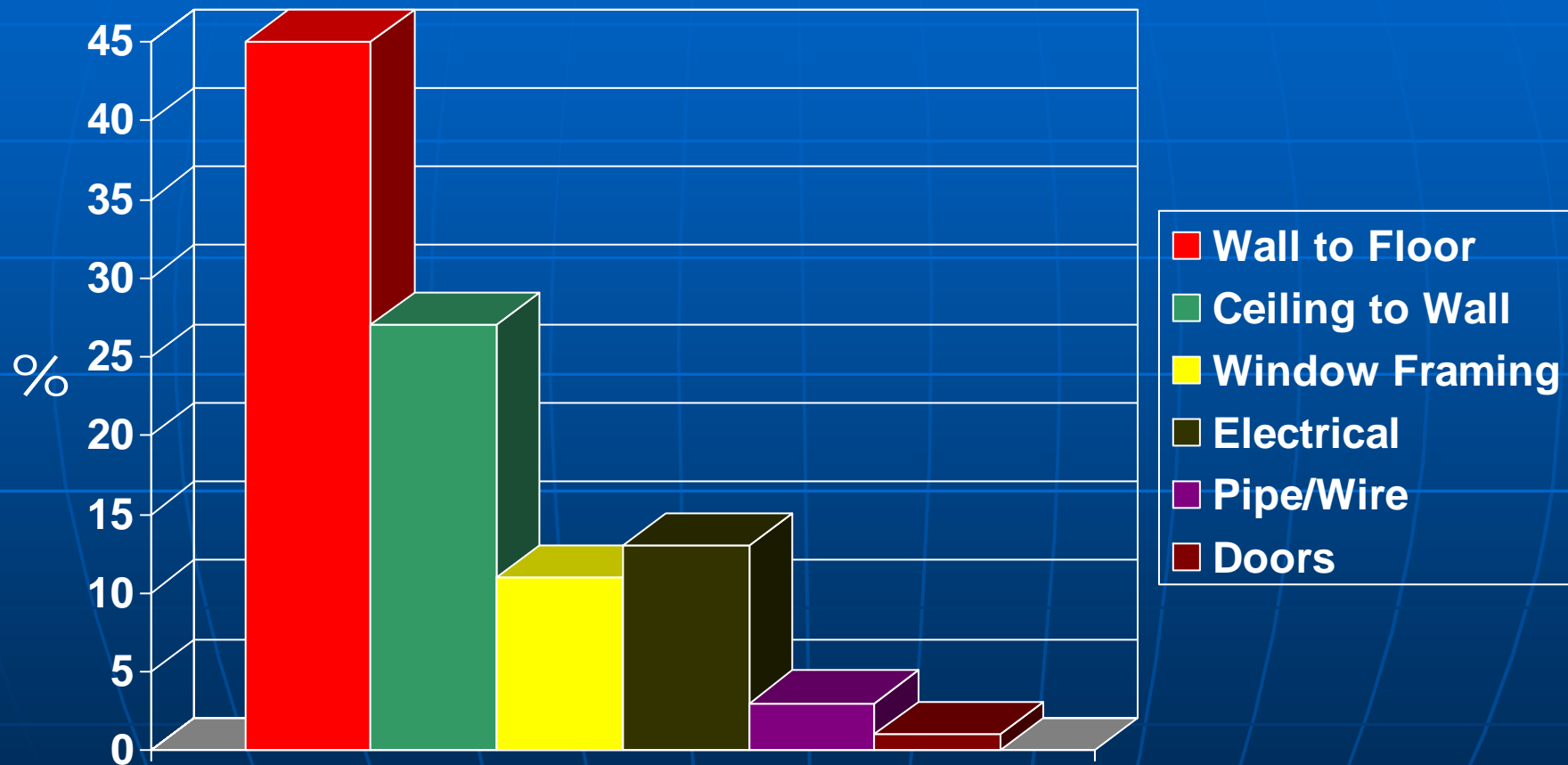


Chart from LSU study

Air Infiltration Pathways In Unsealed Framed Wall Cavities



ASHRAE research project RP 438, Colliver, D.G.; 1994

Driving Forces

- Pressure differential causes
 - Wind/air movement
 - Stack effect
 - Mechanical systems
 - Temperature gradients (stack effect)
- Gases/vapors move:
 - From areas of higher concentration to areas of lower concentration
 - From warmer areas to cooler areas
- Physical Disturbances

HVAC - Driving Force

- Air Currents
- Pressure Differentials – Unbalanced HVAC
- Exhaust fans
 - Kitchen
 - Bath
 - Whole house
 - Attic
 - Clothes dryer
- Leaking Ducts
 - Pressurize some spaces, depressurize others

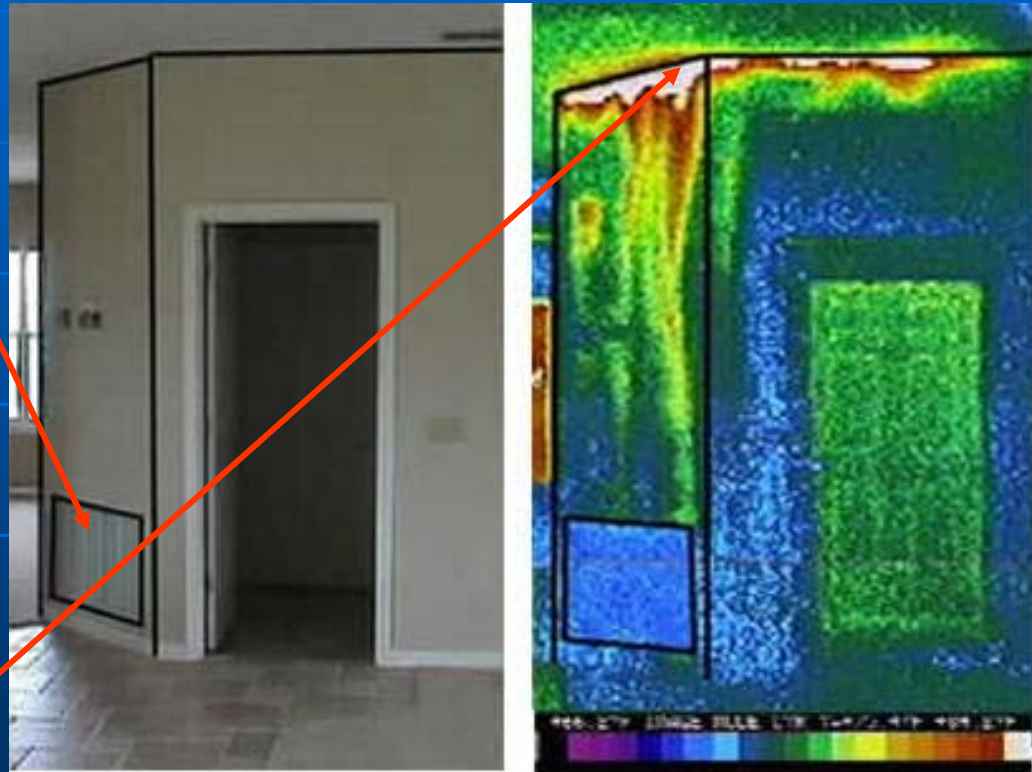
Vibration & Disturbance

- Disturbance of a few square feet of vinyl wall covering over moldy drywall increased Asp/Pen in air concentration by 1,000X



Driving Force

- Reduced air pressure = driving force
- Air infiltration from attic = pathway in wall framing



More Pressure Differential Illustrations

- Adjoining closed rooms with unequal supply and return ventilation rates
- Leaking supply ducts in attics or crawlspaces can place occupied space under negative pressure
- “Stack-Effect” can create negative pressure on lower floors and positive pressure on upper floors

Air Pressure Differentials

- A recent study¹ determined that mechanical exhaust in apartment buildings caused negative pressure of 5 – 20 Pa.
- This resulted in transport of 1 – 3 micron spores thru floor cracks from the crawlspace.
- Larger spores were transported thru a 15 mm pipe penetration.

1 – M. Airaksinen, J. Kurnitski, P. Pasanen, O. Seppänen; (2004) Fungal Spore Transport Through a Building Structure", *Indoor Air 2004*: 92-104

Hidden Mold Impact

- Case 1 – new home – midwest locale
 - Odor complaint
 - A few small patches of visible mold in basement ($< 1 \text{ ft}^2$ – floor joists & sub-flooring)
 - Otherwise, no visible mold or water staining
 - Home was immaculate

Case 1 Air Testing

Location	Viable Mold cfu/m ³	Dominant Species
Outdoor	483 (ave.)	Cladosporium
1 st fl lv rm	940 (ave.)	89% Asp/Pen
1 st fl kit	995 (ave.)	94% Asp/Pen
1 st fl fam rm	1068 (ave.)	90% Asp/Pen
2 nd fl rms	446 (ave.)	87% Asp/Pen
Basement	822 (ave.)	93% Asp/Pen

Case 1 Investigation

- Surface samples of small areas of visible mold on basement lumber showed *Penicillium* and various *Phylloplanes*
- No current moisture found
- Insulation samples pulled from some 1st floor wall cavities showed a range of non-detect to significant amounts of *A. Versicolor*, *A. glaucus* or *Aureobasidium pullulans*

Case 1 Outcome

- Owners were allergic to mold
- Owners moved out
- Builder was sued
- Suspected that construction delay in installation of exterior brick cladding allowed water infiltration of insulated wall cavities
- Air movement in wall cavities believed to deliver mold spores into living space
- Final resolution unknown

Hidden Mold Impact

- Case 2 – Southern Climate Home
 - Musty odor throughout house
 - No significant visible mold on interior surfaces
 - Hidden mold growth found in attic and wall cavities

Case 2 Air Testing

Location	Spore Trap Mold S/m ³	Dominant Species
Outdoors	5994 (ave.)	50% Asp/Pen 50% Basidios
Fam Rm 1 st fl	849 (ave.)	42% Asp/Pen 15% Stachy
Attic	29,470 (ave.)	97% Asp/Pen
Bedrooms – 2 nd fl	21,263 (ave.)	87% Asp/Pen

Case 2 Surface Sampling

- Surface samples/bulks from attic, wall and ceiling cavities showed:
 - Asp/Pen species dominated
 - Stachybotrys present in significant % in some samples

Case 2 Outcome

- AC supply ducts in attic leaked air
 - AC air leaks caused condensation to form on attic ducts
 - Air leaks also caused interior of home to be under negative pressure (-3 to -10 Pa)
 - Numerous unsealed ceiling and wall penetrations found
 - Infiltration of warm humid outdoor air thru walls (est. 200-400 cfm) = condensation = mold growth
 - Infiltrating air carried spores into living spaces

Hidden Mold Impact

- Case 3- West Coast Climate
 - Apartment building
 - History of leaks in some units due to wind driven rain
 - No visible mold on exposed interior surfaces
 - Hidden mold growth found in wall cavities

Case 3 - Air Testing

Location	Viabile Mold cfu/m ³	Dominant Species
Outdoors	320 (ave.)	74% Clad sp. + Alternaria
		19% Asp/Pen
Leaky Apts.	646 (ave.)	15% Clad sp. + Alternaria
		76% Asp/Pen
Non-Leaky Apts.	493 (ave.)	66% Clad sp. + Alternaria
		11% Asp/Pen

Case 3 Leaking Apartment



Typical exterior wall – no visible mold (atypical air test)



Interior cavity with hidden visible mold

Case 3 - Outcome

- Defects in building envelope allowed wind driven rain to infiltrate wall cavities of some apartments.
- Hidden mold growth developed in those wall cavities.
- Air infiltration carried spores from the wall cavities into the living space of those apartments.
- Profile of airborne mold taxa significantly different in affected apartments.

Speaker Contact Information:

Gary N. Crawford, CIH

Boelter Associates, Inc.

1300 Higgins Rd.

Park Ridge, IL 60068

847/685-9245

www.gcrawford@boelterassociates.com