Mold

Reference:
2004 Institute of Medicine
Damp Indoor Spaces & Health
Committee on Damp Indoor Spaces and Health
370 pages
Spores & Fragments of Fungi

- Fungal spores: 2 – 10 μ
  - Penicillium & Aspergillus produce lots of spores, disseminate easily
  - Stachybotrys & Chaeromium produce fewer spores, usually wet and disseminate much less
  - 10μ spore falls in 5mn, 5μ spore falls in 20mn
  - Resuspension by walking, cleaning ↑ conc by 1.5 to 10
- Mycelium fragments < 1 μ
  - Role unknown in causing health effects
  - Penetrate up to alveoli
- In comparison bacterial spores are ~1 μ

Species

- >100,000 known species
- >1,000 species common in USA
- ~ 20 species common in homes

<table>
<thead>
<tr>
<th>Acremonium</th>
<th>Alternaria</th>
<th>Aspergillus</th>
<th>Botrytis</th>
<th>Chaetomium</th>
<th>Cladospori</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doratomyces</td>
<td>Eurotium</td>
<td>Fusarium</td>
<td>Geomyces</td>
<td>Gloucladium</td>
<td>Humicola</td>
</tr>
<tr>
<td>Mucor</td>
<td>Oidiodendron</td>
<td>Paecilomyces</td>
<td>Penicillium</td>
<td>Phialophora</td>
<td>Rhizopus</td>
</tr>
<tr>
<td>Rhodotorula</td>
<td>Scopulariopsis</td>
<td>Stachybotrys</td>
<td>Torula</td>
<td>Trichoderma</td>
<td>Tritrichium</td>
</tr>
<tr>
<td>Ulocladium</td>
<td>Verticillium</td>
<td>Wallemia</td>
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Diagnosing Environmental Mold

Look and sniff
If it didn’t get wet, doesn’t look moldy, doesn’t smell moldy, then it is unlikely to be meaningfully contaminated.

Exposure pathway

Inhalation primary exposure pathway
- Spores, hyphae, conidia or byproducts
- Mold or byproducts must be airborne and respirable
- Microbial VOCs are volatile
- Other mold constituents/byproducts

Factors affecting respirability

Particles larger than 5 microns not respirable
5 microns to 0.005 micron respirable
Mold Allergens, Irritants, Toxins & More: Health Effects

**Fungal armory**

**Allergens**
Interaction of IgE antibodies with specific antigens (pollens, dusts, molds)
Followed by histamine release and inflammation

Major Allergens:
- Aspergillus fumigatus Asp f1, Asp f2
- Malassezia furfur Mal f1
- Trichophyton tonsurans Tri t1
- Penicillium chrysogenum
- Penicillium citrinum

**Irritants**
Microbial volatile organic compounds (mVOCs)
- Lightweight, typically with noxious odors
- Odorons: smell of mold (alcohols, aldehydes, ketones, lactones, hydrocarbons, terpenes, sulfur, nitrogen)
- Inked to irritation, headaches, fatigue, nausea

Fungal cell walls fragments: acetyl-glucosamine polymer
- Fibrils β1→3 glycans, pieces of cell walls
- Gram-negative-endotoxin-like effects, organic toxic dust syndrome

**Mycotoxins**
Mycotoxins often shown to occur
- In spores or hyphal fragments
- On mold-infected materials
- On house dust from damp, moldy buildings
- Seldom directly in the air

Few are volatile, most semi-volatile, Only partially water soluble
Species specific dissemination:
- Asp. & Pen: 1-2μ, easily dispersed
- Stachybotrys: 5-7 μ, wet and slimy during sporulation

Large dose: horse eating from hay full of mold and mycotoxin
????: Inhalation from indoor air
### Immuno-Active Mycotoxins

<table>
<thead>
<tr>
<th>Mycotoxin</th>
<th>Fungi Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aflatoxin</td>
<td>Aspergillus flavus, parasiticus</td>
</tr>
<tr>
<td>Ochratoxin</td>
<td>Asp. ochraceus, Pen. verricosum,</td>
</tr>
<tr>
<td>Sterigmatocystin</td>
<td>Asp. versicolor, nidulans</td>
</tr>
<tr>
<td>Gliotoxin</td>
<td>Asp. fumigatus</td>
</tr>
<tr>
<td>Cyclopiazonic acid</td>
<td>Asp. spp, Pen. spp</td>
</tr>
<tr>
<td>Citrin</td>
<td>Pen. spp</td>
</tr>
<tr>
<td>Patulin</td>
<td>Asp. spp, Pen. spp</td>
</tr>
<tr>
<td>Trichotecenes</td>
<td>Stachybotrys chartarum</td>
</tr>
<tr>
<td>Cyclosporin A</td>
<td>Stachybotrys chartarum</td>
</tr>
<tr>
<td>Streptomyces sutubaensis</td>
<td></td>
</tr>
<tr>
<td>Zearalenone</td>
<td>Fusarium spp</td>
</tr>
<tr>
<td>Rapamycin</td>
<td>Streptomyces hygroscopicus</td>
</tr>
</tbody>
</table>

### Neurotoxic Mycotoxins

<table>
<thead>
<tr>
<th>Mycotoxin</th>
<th>Fungi Species</th>
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<tbody>
<tr>
<td>Penitrem A</td>
<td>Pen cyclopium, verruculosum</td>
</tr>
<tr>
<td>Penitrem E</td>
<td>Pen. crustosum,</td>
</tr>
<tr>
<td>Aflatrem</td>
<td>Asp. flavus</td>
</tr>
<tr>
<td>Roquefortine</td>
<td>Asp. commune, palitans, crustosum</td>
</tr>
<tr>
<td>Verrucologen</td>
<td>Pen. verrucolosum</td>
</tr>
<tr>
<td>Verrucosidin</td>
<td>Pen. verrucolosum</td>
</tr>
<tr>
<td>Patulin</td>
<td>Asp. spp, Pen. spp</td>
</tr>
<tr>
<td>Fumitrem B</td>
<td>Asp. fumigatus</td>
</tr>
<tr>
<td>Cyclopiazonic acid</td>
<td>Pen. cyclopium, Asp. flavus</td>
</tr>
<tr>
<td>Territrem</td>
<td>Asp. terreus</td>
</tr>
<tr>
<td>Citreoviridin</td>
<td>Pen. citroviride Asp. terreus</td>
</tr>
<tr>
<td>Ochratoxin A</td>
<td>Asp. ochraceous, Pen. verrucosum</td>
</tr>
<tr>
<td>Gliotoxin</td>
<td>Asp. fumigatus</td>
</tr>
<tr>
<td>Trichothecenes</td>
<td>Stachybotrys chartarum</td>
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</tbody>
</table>

### Neurotoxicity

#### Neurotoxic effects:
- Fatigue
- Headache
- Memory loss
- Depression
- Mood swings

Sensory irritation: Irritative stimulus to nerve ending

VOC from fungus or building materials

(new bldg = 25 mg/m³)

Categories:
- A-Tremor generating
- B-Paralyzing
- C-Neuro transmitter interference

Animal consumption: Rye grass staggers

### Carcinogenicity

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</tr>
<tr>
<td>Sterigmatocystin</td>
<td>Asp. versicolor, flavus, Pen. luteum,</td>
</tr>
<tr>
<td>Ochratoxin</td>
<td>Asp. ochraceus, alutaceus, Pen. verrucosum, viridicatum, cyclopium,</td>
</tr>
<tr>
<td>Zearalenone</td>
<td>Fusarium graminearum</td>
</tr>
<tr>
<td>Penicillin Acid</td>
<td>Asp. Ochraceus</td>
</tr>
<tr>
<td>Luteoskyrin</td>
<td>Pen. Islandicum</td>
</tr>
<tr>
<td></td>
<td>Liver, lung</td>
</tr>
<tr>
<td></td>
<td>Liver rats/mice</td>
</tr>
<tr>
<td></td>
<td>Kidney, bladder</td>
</tr>
</tbody>
</table>

### Nephrotoxicity

### Dermal toxicity

- Trichothecenes
- Skin reddening, edematous damage to skin
- One example of worker exposed to Stachy<br>trichothecene: painful skin lesions

### Animal consumption: Rye grass staggers
Health Effects Associated with Molds

Primary complaints are respiratory

Immunocompromised: Infection

Allergic individuals:
- Hay-fever-like symptoms: runny nose and eyes
- Asthma: Exacerbation of symptoms in people with asthma

Others:
- Respiratory tract irritation

Sensitive groups
- People with allergies
- People with chronic respiratory illness
- Immune compromised individuals
- Hospital settings: 10% of nosocomial infections

Infections

Immunocompromised: High dose chemotherapy, transplant patients; Aspergillus, Fusarium

Source: Indoor fungi, not specially those which flourish in damp environments

Cystic fibrosis, asthma, COPD: Colonization then infection; Aspergillus

Normal children: Several studies showed association between bronchitis, LRTI and moldy indoor environment

Brunekreef, 1989; Six US cities; OR 1.17<1.48<1.87

Dales & Miller, 1999; Ontario; OR 7.76<1.51<3.02

Allergies

General allergy symptoms, signs: puffy eyes, runny nose, hives, eczema; elevated total serum IgE

Assessment of specific sensitivities: scratch tests (archaic?); elevated serum IgE for particular allergens

Asthma

Reversible airway obstruction determined by:
- symptoms of cough, wheezing & chest tightness
- reduction in peak expiratory flow
- response to inhaled bronchodilators
- bronchoconstriction following methacholine challenge

Allergic asthma IgE mediated

Intrinsic non-allergic variant: No detectable sensitization, Low IgE concentration, Irritant response

Asthma exacerbation

Self report of physician diagnosed asthma and self report of asthma when exposed to damp /moldy indoors

21 studies: OR 0.8 to 5, Most OR 1 to 3, 7 Sig

Examples: asthma exacerbation and mold indoor

Zock, 2002: 19,000 subjects; OR 0.94<1.13<1.35, Kilpeläinen, 2001: 10,667 subjects; OR 1.48< 2.21< 3.28

Asthma development: Difficulty in ascertainment of new onset asthma, Difficulty in children <3yrs because of bronchial reactivity

8 studies: OR 0.4 to 4, Most 1.5 to 3, Sig 7

Association with indoor damp environment and development of asthma. Not clear which of exposure to fungi, bacteria, constituents or emissions, dust mites, roaches is responsible

Not sufficient evidence to establish association between asthma development and indoor fungus

Hypersensitivity Pneumonitis: Asthma-like immune-mediated lung disease

Characterized by cough, chest tightness & wheezing; Fever, myalgias & fatigue

Restrictive pattern on pulmonary function tests

Inflammation in the alveoli, not the airways: Lymphocytic infiltrate on bronchoalveolar lavage

Immune-mediated in sensitized individuals

Interstitial fibrosis on lung biopsy

Related to cold-contaminated humidifiers and ventilation systems

Relation to mycotoxin raised by Trout (2001) but

- Minute fraction of exposed develop disease
- No dose relationship
**Irritation**

**Upper Respiratory Tract**
Nasal congestion, Sneezing, runny, itchy nose, common cold
Allergic rhinitis (Hay fever)
Hoarseness, sore throat
Eye irritation
14 studies; 31,000 participants; OR from 0.94 to 4.6; Most OR 1.1 to 1.9; 10 Sig

**Mucous Membrane Irritation Combination of URT and LRT irritation**
Rhinorrhea, nasal congestion, sore throat AND cough, lower respiratory tract symptoms
Commonly seen in agricultural exposure to organic dusts
Mucosal hyper-reactivity with release of pro-inflammatory cytokines (TNFα, IL-1, IL-6, NO)
Mold spores stimulates pro-inflammatory cytokine release from macrophages
One experimental study with high level exposure to fungal spores NOT associated with high NO or pro-inflammatory cytokines
Insufficient information to draw conclusions

**Lower Respiratory Tract**

**Cough**
22 studies; OR 0.7 to 5.0; Most OR 1 to 2; 14 Sig
Consistent statistical association between cough and damp indoors / moldy environment

**Wheeze**
Labored breathing, chest tightening; Inflammatory process in non-asthmatics; Asthmatics
20 studies; OR 0.8 to 6; Most OR 1.2 to 2; 17 Sig
Consistent statistical association between cough and damp indoors / moldy environment

**Dyspnea, shortness of breath**
Lung or heart disease
4 studies; 2 Sig; OR 2 to 3
Associated with damp environment but small # of studies; Association with mold inadequately proven

**Asthma and COPD**
Measured with Forced Expiratory Volume (FEV)
Bronchial hyper-responsiveness or bronchial hyper-reactivity = ▼ of ≥20% in FEV after metacholine or histamine challenge
Hyper-reactivity ➔ cough & wheezing
Seen in normal individuals, asthmatics, chronic airway disease, organic dust exposure
No sufficient evidence: not all studies consistent
**Sinusitis: Inflammation of paranasal sinus**
Usually microorganisms; Edema prevents draining of increased mucus production; Microbial super-infection
Fungi commonly isolated from nasal secretions of healthy and chronic rhino-sinusitis
   91% healthy volunteers w positive fungal culture
   91% chronic sinusitis w positive fungal culture
   33 genera isolated, mean 3.2 species /person
No definitely proven association

**COPD**
Disease characterized by progressive airflow limitation
Associated with abnormal inflammatory lung response to noxious particles or gases
Smoking primary cause
Other causes: ETS, air pollutants, organic and inorganic dust
Not fully reversible
Immuno-compromised + COPD at higher risk
Cause of COPD: insufficient evidence

**Pulmonary Hemorrhage in Children or Hemosiderosis**
Abnormal accumulation of hemosiderin in lung tissue
Diffuse bleeding and hemorrhage in alveoli
Reported with
   Heiner syndrome (hypersensitivity to caw’s milk)
   Auto-immune diseases: Goodpasture Syndrome, Wegner’s granulomatosis, celiac disease, high dose chemotherapy
   Particularly infants and pretermes
   Recurrent episodes of fever, tachypnea and pm bleeding
Horse
Cluster of 8 cases in Cleveland 1993/4

**Farmer’s Lung**
Growth of fungi found in hay, straw or grain dust within lungs

**Inhalation Fevers**

**Organic Dust Toxic Syndrome (ODTS)**
Self limiting non-infectious febrile illness
After organic dust inhalation exposure
Malaise, myalgia, dry cough, fever, nausea, headache
Similar to acute hypersensitivity pneumonitis but no prior sensitization
No infiltrates, no restriction
Not associated with fungus indoor, only in occupation setting

**Humidifier Fever**
Febrile reaction with resp tract symptoms, Chest Xray OK
No association with fungus exposure
Serologic Diagnosis Not effective
People are all constantly exposed to fungi
Most people may have antibody response to those fung
Lack of specificity of antifungal antibodies: many cross-reactive
Antibody tests are of very limited utility in making a diagnosis.

**Mold Concentrations:** Studies comparing residences and offices

<table>
<thead>
<tr>
<th>Klánová, 2000</th>
<th>68 Rooms</th>
<th>Concentration cfu/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-No complaints, no molds 20</td>
<td>0-230</td>
<td></td>
</tr>
<tr>
<td>2-Complaints, no molds 20</td>
<td>0-140</td>
<td></td>
</tr>
<tr>
<td>3-No complaints, visible mold 10</td>
<td>60-3,190</td>
<td></td>
</tr>
<tr>
<td>4-Complaints, visible mold 18</td>
<td>120-17,930</td>
<td></td>
</tr>
</tbody>
</table>

Note the inconsistencies:
(3) has 3,190 and no complaints; (4) has 120 with complaints

**No Mold Standards**
No federal or state standards for indoor airborne concentrations of mold
No threshold limit values (TLVs) for human exposure

**Why?** Individual sensitivities vary greatly
No correlations established between health effects and measurements

OBJECTIVE: To review the available literature on the subject of fungi (molds) and their potential impact on health and to segregate information that has scientific validity from information that is yet unproved and controversial. DATA SOURCES: This review represents a synthesis of the available literature in this area with the authors' collective experience with many patients presenting with complaints of mold-related illness. STUDY SELECTION: Pertinent scientific investigation on toxic mold issues and previously published reviews on this and related subjects that met the educational objectives were critically reviewed. RESULTS: Indoor mold growth is variable, and its discovery in a building does not necessarily mean occupants have been exposed. Human response to fungal antigens may induce IgE or IgG antibodies that connote prior exposure but not necessarily a symptomatic state. Mold-related disease has been discussed in the framework of noncontroversial and controversial disorders. CONCLUSIONS: When mold-related symptoms occur, they are likely the result of transient irritation, allergy, or infection. Building-related illness due to mycotoxicosis has never been proved in the medical literature. Prompt remediation of water-damaged material and infrastructure repair should be the primary response to fungal contamination in buildings.

Mycotoxins are well studied when toxins are ingested in food; Almost all real episodes human illness due to fungal toxins have followed ingestion of the toxin. Very little information on inhalational route particularly in humans with indoor contamination

The role of toxigenic fungal exposure has yet to be determined - IOM, 2004 Damp indoor spaces and health

Anecdotal reports of health problems attributed to mold often dominate mass-media attention, but they are not a source of reliable information.”

Despite this list of impressive effects in some settings, the vast majority of the time it has been difficult to link a particular fungal toxic to a particular effect or complaint. The toxins are generally present in low quantities and only occasionally will enough toxin be present acutely to cause a dramatic and clearly linked syndrome. Mycotoxins are relatively large and non-volatile molecules (that is, they do not readily release into the air). Thus, very direct contact with the mycotoxin is required.

Although evidence was found of a relationship between high levels of inhalation exposure or direct contact to mycotoxin-containing molds or mycotoxins, and demonstrable effects in animals and health effects in humans, the current literature does not provide compelling evidence that exposure at levels expected in most mold-contaminated indoor environments is likely to result in measurable health effects. Even though there is general agreement that active mold growth in indoor environments is unsanitary and must be corrected, the point at which mold contamination becomes a threat to health is unknown. Research and systematic field investigation are needed to provide an understanding of the health implications of mycotoxin exposures in indoor environments. Robbins, CA 2000. Health effects of mycotoxins in indoor air: A critical review. Appl. Occup. Environ. Hyg. 15 (10): 773-784
Guidelines
1980 USDA Bulletin...control dampness, use bleach
1984, 1996: International Society of Indoor Air Quality and Climate (ISIAQ) Control of Moisture Problems Affecting Biological Indoor Air Quality (Flannigan & Morey)...moisture control, ventilation from outside, respirators
1989, 1999: Bioaerosols Committee, American Conference of Government Industrial Hygienists (ACGIH)...vacuuming, HEPA filtration, caution with biocides
1992: Repairing your Flooded Home, American Red Cross (ARC) & Federal Emergency Management Agency (FEMA)
1992: American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE)...remediation with containment, air leak barrier
1993: New York City Dept of Health Guidelines for Remediation of Stachybotrys
2000: New York City Dept of Health Guidelines for Remediation of Fungi in Indoor Environments
2001: Environmental Protection Agency (EPA) Mold Remediation in Schools and Commercial Buildings
Preventing Indoor Mold
Respond quickly to moisture problems
Dry wet materials within 48 hours
Replace water-damaged materials
Regularly inspect for leaks, mold growth, and musty odors

Preventing Indoor Mold
Maintain indoor relative humidity below 60%
   Ideal 30% - 50%
   Air conditioners and/or de-humidifiers
   Exhaust fans or open windows in bathrooms, kitchens
   Vent clothes dryers to outside
   Reduce condensation

Mold Remediation Principles

Identify and control moisture sources before remedial actions

Inspect for visible mold and damage to determine scope of remedial activities and necessary control measures

Small area cleanups may be performed by residents or building custodial staffs

Remove heavily contaminated porous materials
   Biocides, antimicrobial agents, ozone not adequate substitutes

Remediation of heavily contaminated areas may require complex contaminant controls and careful work practices
Industrial hygienists and/or environmental consultants often required to oversee or perform prudent cleanup processes
Preventing Indoor Mold

Mold Clean-Up 101

Do-It-Yourself (<10 ft²)

Hard, non-porous surfaces: Damp wipe
Hard, semi-porous: Scrub surface
Porous materials: Discard and replace
Bag and seal moldy materials; Disposal same as construction debris

Personal Protection: Use common sense

Wear goggles that do not have ventilation holes or use a full-face respirator
Wear water-resistant boots and gloves and disposable protective clothing (such as a Tyvek™ suit)
Use duct tape to seal the gaps around the ankles and wrists. Wear a water-resistant disposable protective suit for wet work. Discard your protective suit at the end of your workshift.

Use a NIOSH-approved respirator

To get a good fit: fit-testing and medical clearance at occupational medicine clinic.

For small jobs a NIOSH-approved N-95 respirator may be used. NIOSH-certified N-95 respirators will have “N95” and “NIOSH” printed on the facemask. These respirators will remove particles (such as mold spores) from the air.

For large or dusty jobs, a full face piece air-purifying respirator with a particulate filter, or a higher level protection (such as a powered air purifying respirator with a particulate filter) is needed.

Air Ducts

This area is a source of great confusion; Exceptions exist;
Short answer: NO, ducts do not need to be cleaned
Cleaning can shake things loose and make situation worse

**Professional Remediation**

When: Large area of contamination, Health conditions not permitting
Who: Environmental consultants/engineers  
Industrial hygienists  
Flood restoration specialists  
Asbestos remediators  
How to locate: Yellow pages; Professional associations  
Considerations: Industry not [yet] regulated; Check with Better Business Bureau; 
Referrals / reputation  
Experience, training, professional affiliations, certifications, degrees

**NIOSH / US EPA**

*Building Air Quality: A Guide for Building Owners and Facility Managers*

**US EPA**

*Indoor Air Quality Tools for Schools: IAQ Coordinator's Guide*
http://www.epa.gov/iaq/schools/tfs/guidea.html

**AIHA brochure**

*Guidelines for Selecting An Indoor Air Quality Consultant*

Successful Remediation

A determination must be made that remediation has been completed and that the space is suitable for re-occupation. Such determinations are necessarily subjective because there are no generally accepted health-based standards for acceptable concentrations of fungal spores, hyphae or metabolites in the air (ACGIH 1999, AIHA 2001)

**Bottom Line**

Moisture control is key  
Respond quickly  
If moisture problem is not fixed, mold will return  
All indoor mold should be treated the same, with regards to: 
  - Cleaning / removal  
  - Personal precautions  
  - Prevention