Indoor Air Quality Assessments: Mould

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National Collaborating Centre for Environmental Health
Centre de collaboration nationale en santé environnementale

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An Agency of the Provincial Health Services Authority

Outline

Introduction

- What is Mould?
- Sources
- Health effects

Sampling and Interpretation

- Sampling methods
- Interpreting results (example lab reports)

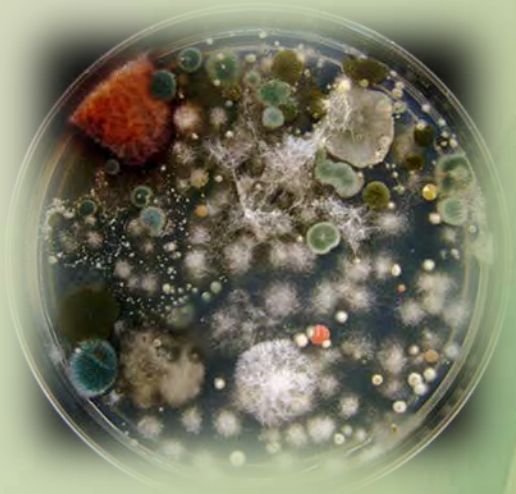
Management

- Education
- Remediation - see resources

Introduction

What is Mould?

- **Moulds are multi-cellular spore-forming filamentous organisms**
  - Ubiquitous, outdoor and indoor
  - >100,000 reported species, few hundred are relevant to human exposure
  - Saprophytes (live off dead organic matter), parasites, symbionts
- **Growth requires**…
  - O_2
  - Organic carbon source
  - Temperature (ideal = 18-32°C)
  - Time
  - **Moisture (e.g., RH >60%)**
    - **most important and only factor that can be controlled indoor**



Kathie Hodge
http://www.flickr.com/photos/cornellfungi/5613739709/

Sources

- Walls, floors and ceilings, wallpaper
- Insulation, carpet,
- Furniture, mattress
- Paper, cardboard
- Food, oil
- HVAC
- Dust
- Plants
- Soil
- Other biodegradable organic materials, even in small amounts or parts of seemingly inorganic substances (e.g., residue/condensation on glass, plastics, caulking)

Concentrations are generally higher outdoor vs. indoor

Health Effects

- **Irritation**
  - Eyes, skin
  - Upper RT
    - Nose, throat irritation
  - Lower RT
    - Cough, wheezing, shortness of breath
- **Infection** (opportunistic)
- **Immunological reactions**
  - Asthma symptoms
  - Hypersensitivity pneumonitis (inflammation of alveoli)
  - Allergic rhinitis, sinusitis, dermatitis

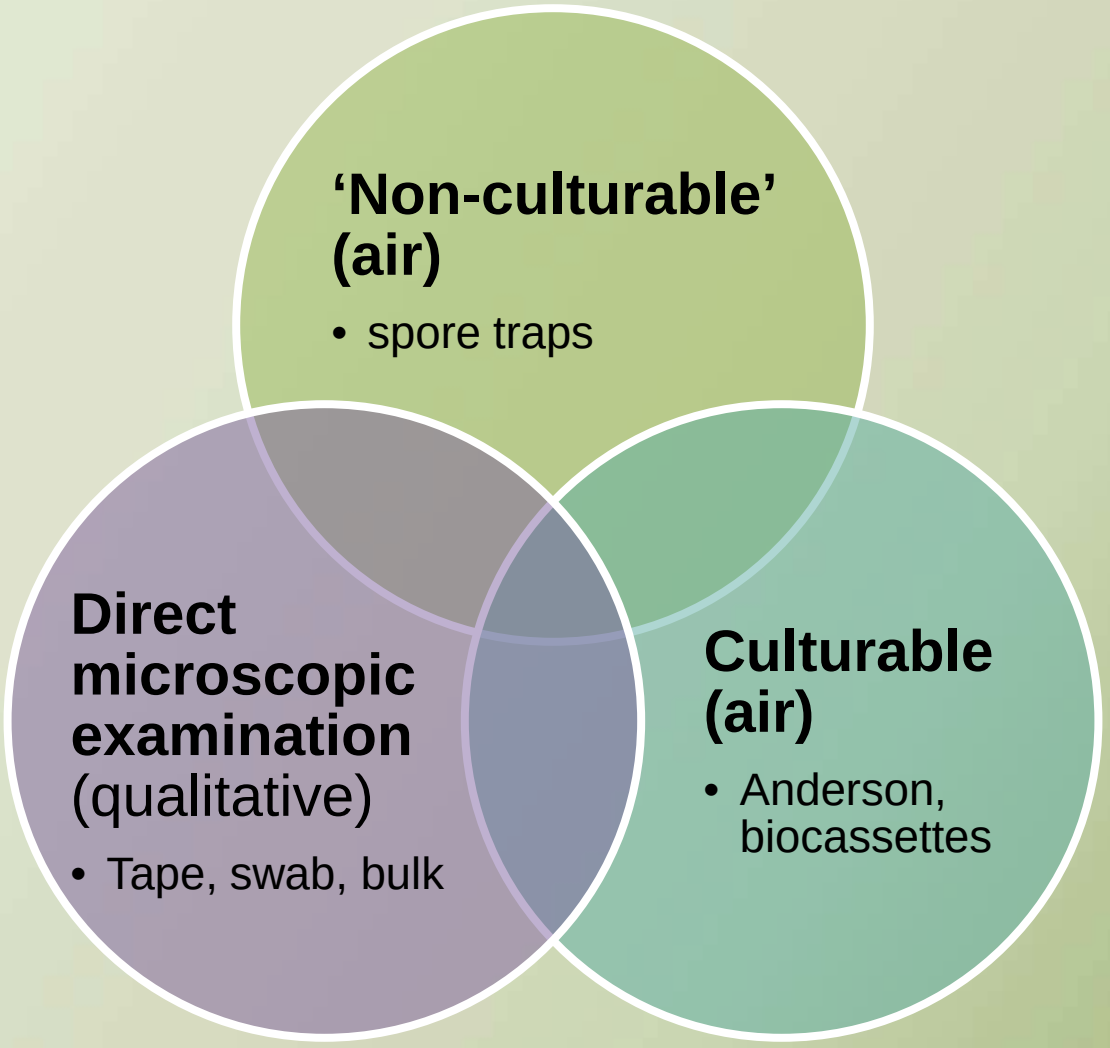
Vulnerable populations:
immunocompromised (HIV/AIDS), immunosuppressed (transplant, chemotherapy patient);
those with allergies, chronic underlying respiratory disease (COPD, asthma); infants, elderly

Sampling & Interpretation

Many factors affecting the composition of mould in the air…

- Growth + distribution
- Note outdoor and indoor conditions
- A few examples…
  - Climate
    - temperature, season, time of day,
  - Aerosolization
    - Wind, rain, anthropogenic activity, turbulence
  - Indoor pets, plants, etc.

Sampling methods



Non-culturable Fungi Air Sampling

Spore traps (e.g., air-o-cells)

↓

Sampled fungi (viable/non-viable) are analyzed under microscope

↓

Used for determining total levels of fungi in air

- Can provide…
  - ID to genus level
  - Concentration (spores/m^3)
  - Genus-level comparison between samples

EMLab P&K
http://www.emlab.com/m/store/003-2022-01_Lg.jpg

Culturable Fungi Air Sampling

Andersen, biocassettes, RCS, etc.

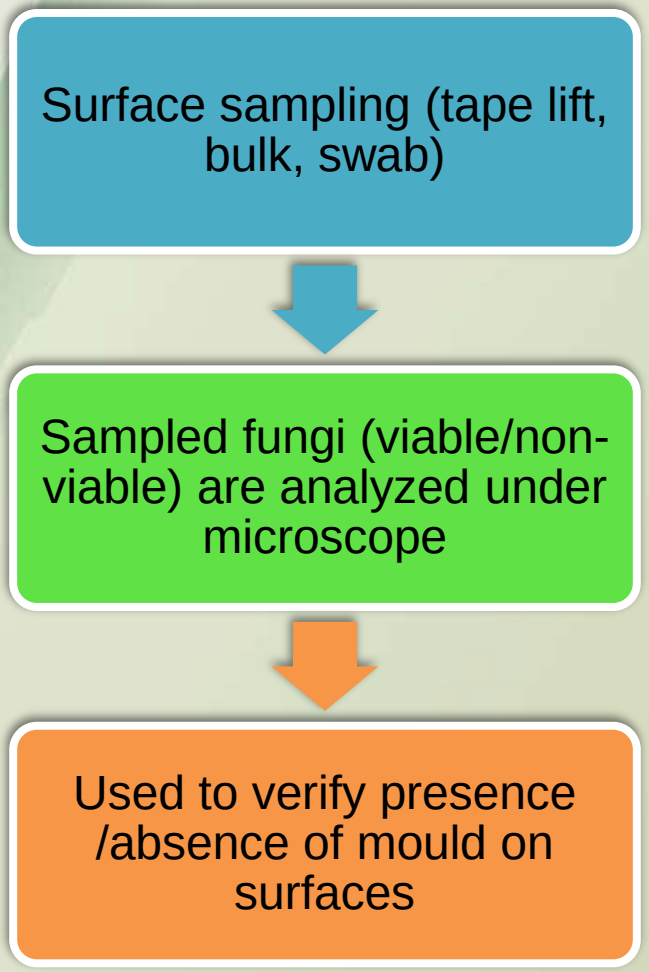
Sampled fungi are collected onto growth media; subsequently enumerated and isolated for ID

Used for determining species and viability of fungi in the air

- Can provide…
  - ID genus + species (e.g., *Aspergillus, Penicillium*)
  - Concentration (CFU/m^3)
  - Species-level comparison between samples

EMLab P&K
http://www.emlab.com/m/store/012-3347-00_Lg.jpg

Surface Sampling



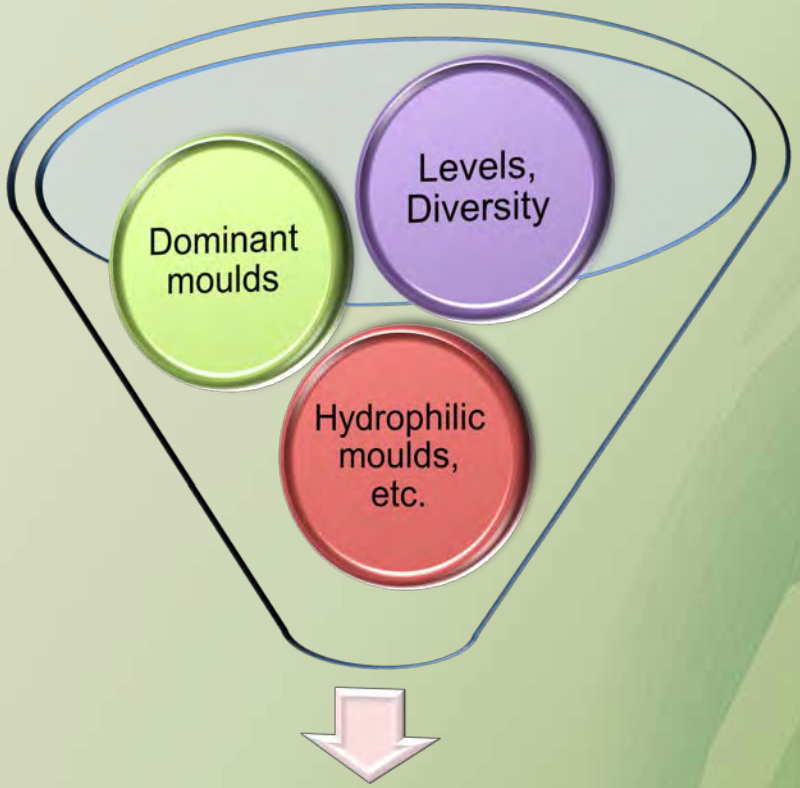
- Can provide…
  - relative level of mould on a surface (qualitative, genus level)
  - information on whether viable fragments or spores are present
  - information on background debris

Interpreting Results – Compare Indoor vs. Outdoor (control)

Anaylze lab results…

- ‘Expected’ moulds and levels between…
  - Suspect areas…
    - **indoor** air
    - surfaces
  - ‘Control’/baseline areas…
    - **outdoor** air
    - non-suspect areas/rooms

- Any potential indicators of indoor mould/dampness?
  - further investigation?



Interpreting Results – Potential indicators

Level

- spores/m^3, CFU/m^3, # hyphal fragments/m^3: **Indoor > outdoor**

Diversity

- Mould (genus/species) ID'ed in indoor sample are **dissimilar** to those in outdoor sample
- presence of a genus/species in indoor **but NOT** outdoor sample

Dominance

- mould that are dominant in indoor sample are **dissimilar** to those in outdoor sample

Interpreting Results – Potential indicators

These are not commonly found in indoor air:

- Rusts, smuts (plant pathogens/fungi)
- Pollen, insect parts
- Hydrophilic fungi

- Typical hydrophilic fungi
  - *Stachybotrys*
  - *Fusarium*
  - *Chaetomium*
  - *Trichoderma*
  - *Ulocladium*
  - *Alternaria*
  - *Acremonium*
  - *Actinomycetes*
  - *Epicoccum*
  - *Rhizopus…*

Table 1. Moisture levels required for growth of selected microorganisms in construction, finishing and furnishing materials

Moisture level	Category of microorganism
High (a_w, > 0.90; ERH, > 90%)	Tertiary colonizers (hydrophilic) *Alternaria alternata* *Aspergillus fumigatus* *Epicoccum* spp. *Exophiala* spp. *Fusarium moniliforme* *Mucor plumbeus* *Phoma herbarum* *Phialophora* spp. *Rhizopus* spp. *Stachybotrys chartarum* (*S. atra*) *Trichoderma* spp. *Ulocladium consortiale* *Rhodotorula* spp. *Sporobolomyces* spp. Actinobacteria (or Actinomycetes)
Intermediate (a_w, 0.80–0.90; ERH, 80–90%)	Secondary colonizers *Aspergillus flavus* *Aspergillus versicolor*[a] *Cladosporium cladosporioides* *Cladosporium herbarum* *Cladosporium sphaerospermum* *Mucor circinelloides* *Rhizopus oryzae*
Low (a_w, < 0.80; ERH, < 80%)	Primary colonizers (xerophilic) *Alternaria citri* *Aspergillus (Eurotium) amstelodami*

World Health Organization. WHO guidelines for indoor air quality: Dampness and mould. Copenhagen, Denmark: WHO, Regional Office for Europe; 2009. Available from: http://www.euro.who.int/document/E92645.pdf

Interpreting Results

Toxigenic/Pathogenic mould

- *Aspergillus fumigatus, A. versicolor, A. niger*
- *Penicillium chrysogenum*
- *Fusarium*
- *Stachybotrys*
- *Trichoderma*
- *Chaetomium…*

- Presence in multiple indoor air samples may support the need for further investigation or remediation

Let’s look at some example lab reports and briefly go over them

- Non-culturable air
- Culturable air
- Surface

Interpreting Results

- Results should not be interpreted in isolation.
  - Needs qualitative risk assessment
    - Information gathering + building history
      - » Complainants, tenants, employees, OHS, managers, maintenance staff (building, custodial, engineer)
    - Visual/Field inspection for mould growth and dampness
    - Professional judgement (may involve a team)
    - Assessment and remediation needs to consider individual site-specific conditions and objectives

Interpreting Results

- Consider:
  - Adequacy of other information to assess for mould growth and dampness
    - What is the need for and reasons for sampling?
  - Sampling method and protocol
    - What are the pros, cons, limitations?
  - Objective of sampling
    - What will be the use of lab results?
    - Do results indicate need for further investigation, remediation, etc.?
    - Testing cannot tell you whether human health effects will occur.

Interpreting Results

- **Visible mould** or dampness is ‘unacceptable’ from hygiene perspective
  - sample only if visual inspection unclear or suspect **hidden mould** (e.g., in crawlspaces)

- If sampling results indicate hidden mould…
  - Is there a reasonable **exposure pathway**?

Management

Education

- Inform on…
  - health effects
  - vulnerable populations
  - potential need for professional assessment/remediation
  - preventing moisture/mould issues

Remediation

- Many resources and guidelines available
  - see additional resources

Mould Resources

NCCEH Evidence Reviews:

- Palaty C, Shum M. Health effects from mould exposure in indoor environments. Vancouver, BC National Collaborating Centre for Environmental Health; 2012 Jul. Available from: http://www.ncceh.ca/en/practice_policy/ncceh_reviews/mould_and_health_effects
- Palaty C. Mould assessment recommendations. Vancouver, BC: National Collaborating Centre for Environmental Health; 2010 Oct. Available from: http://www.ncceh.ca/en/practice_policy/ncceh_reviews/mould_assessment.
- Palaty C. Mould remediation recommendations. Vancouver, BC: National Collaborating Centre for Environmental Health; 2010 Oct. Available from: http://www.ncceh.ca/en/practice_policy/ncceh_reviews/mould_remediation.

EMLab P&K

- Sampling Overview
  - http://www.emlab.com/s/sampling/Sampling.html
- Sample lab reports
  - http://www.emlab.com/app/services/Services.po?c=1
- An index of some commonly encountered fungal genera
  - http://www.emlab.com/app/fungi/Fungi.po
- Glossary
  - http://www.emlab.com/s/sampling/FungalGlossary.html

Mold & Bacteria Consulting Laboratories (MBL)

- Results Interpretation
  - http://www.moldbacteria.com/category/results-interpretation

Guidelines

- Health Canada. Fungal contamination in public buildings: A guide to recognition and management. Ottawa, ON: Health Canada, Environmental and Workplace Health; 1995. Available from: http://individual.utoronto.ca/jscott/fpwgmaqpb001.pdf.

- Health Canada. Fungal contamination in public buildings: Health effects and investigation methods. Ottawa, ON: Health Canada, Environmental and Workplace Health; 2004. Available from: http://www.hc-sc.gc.ca/ewh-semt/pubs/air/fungal-fongique/index-eng.php.

- Health Canada. Residential indoor air quality guidelines - Moulds. Ottawa, ON: Health Canada, Environmental and Workplace Health; 2007 Available from: http://www.hc-sc.gc.ca/ewh-semt/pubs/air/mould-moisissure-eng.php.

- New York City Department of Health and Mental Hygiene. Guidelines on assessment and remediation of fungi in indoor environments. New York, NY: Environmental and Occupational Disease Epidemiology Unit; 2008 Nov. Available from: http://www.nyc.gov/html/doh/downloads/pdf/epi/epi-mold-guidelines.pdf.

- World Health Organization. WHO guidelines for indoor air quality: Dampness and mould. Copenhagen, Denmark: WHO, Regional Office for Europe; 2009. Available from: http://www.euro.who.int/document/E92645.pdf

Books

- Flannigan B, Samson RA, Miller JD, editors. Microorganisms in Home and Indoor Work Environments. 1 ed: CRC Press; 2002.

- Flannigan B, Samson RA, Miller JD, editors. Microorganisms in Home and Indoor Work Environments. 2 ed: CRC Press; 2011.