Historical aspects of bioaerosols

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Are dampness and mould new problems?

- Historical documents exist: people have always known that mold is harmful
- Building practices and technologies have been developed to avoid moisture intrusion
- After WWII, rapid development of element technologies, materials, industrialization
- Moisture control in modern buildings far more difficult than in traditional houses
Leprous plague in the house and what to do about it (Bible)

- The initial responsibilities of the owner and priest are given in Leviticus 14:33-38
- Instructions of what to do after the quarantine of seven days is complete: Leviticus 14:39-42
- Instructions for what happens if leprosy returns to a house after it has been treated: Leviticus 14:43-47
Early studies on indoor air fungi: sources, concentrations, determinants

  - Outdoor air the main source of indoor fungi
  - In a normal house, indoor molds mainly the same as outdoors but in lower concentrations
  - Concentrations fluctuate seasonally
  - In June-October, *Cladosporium* most prevalent indoors; rest of year, *Penicillium*
Early studies on indoor fungi: role of air condition

  - Fewer fungi in air-conditioned hospital
  - In naturally ventilated hospitals: fungi originate from outdoors, bacteria from humans
  - Lower counts and lower RH in air-conditioned homes
Richards (1954) knew the problem of moldy houses:

- In (observably) moldy houses, mold spore content different in constitution and quantity
- "there can be little doubt that in a house which is visibly moldy the residents are exposed to higher concentrations of mold spores than the residents of a normal, clean, dry house"
- Nilsby (1947): 5 cfu/plate in normal vs. 55 cfu/plate in complaint homes
1970ies – respiratory diseases linked with biological dust

- Extensive research on respiratory diseases linked with mold
- E.g. hypersensitivity pneumonitis (allergic alveolitis), farmer’s lung, ODTS, others…
- Mainly occupational diseases linked with exposure to moldy hay or other biological dust
- Exposures and mechanisms not well understood
- **Note:** Cases of similar diseases reported also in association with building dampness and mold although exposure levels much lower

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<table>
<thead>
<tr>
<th>Allergen source</th>
<th>Environmental exposure</th>
<th>Disease</th>
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</thead>
<tbody>
<tr>
<td><strong>Alternaria alternata</strong></td>
<td>mouldy logs</td>
<td>wood pulp-worker’s lung</td>
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<tr>
<td><strong>Aspergillus clavatus</strong></td>
<td>mouldy malt</td>
<td>malt worker’s lung</td>
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<tr>
<td>A. <em>fumigatus</em></td>
<td>mouldy wood chips, mouldy sphagnum</td>
<td>wood chip burner’s lung, greenhouse lung</td>
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<tr>
<td>A. <em>niger</em></td>
<td>enzyme</td>
<td>asthma</td>
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<tr>
<td>A. <em>oryzae</em></td>
<td>acid production</td>
<td>asthma</td>
</tr>
<tr>
<td>Botrytis cinerea</td>
<td>mouldy plants</td>
<td>asthma, greenhouse lung</td>
</tr>
<tr>
<td>Eurotium rubrum (Aspergillus umbrosus)</td>
<td>mouldy hay</td>
<td>farmer’s lung</td>
</tr>
<tr>
<td><strong>Penicillium camemberti</strong></td>
<td>cheese production</td>
<td>asthma, cheese worker’s lung</td>
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<tr>
<td>P. Communaes</td>
<td>mouldy cheese</td>
<td>cheese worker’s lung</td>
</tr>
<tr>
<td>P. Roqueforti</td>
<td>cheese production</td>
<td>asthma, cheese worker’s lung</td>
</tr>
<tr>
<td>Rhizopus stolonifer</td>
<td>sawmills</td>
<td>wood trimmer’s disease</td>
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<tr>
<td>Scopulariopsis brevicaulis</td>
<td>mouldy tobacco</td>
<td>tobacco worker’s disease</td>
</tr>
<tr>
<td>Mixed mould populations</td>
<td>ventilation ducts, mouldy garbage and compost for recycling humidifiers</td>
<td>waste-handling disease, humidifier disease</td>
</tr>
</tbody>
</table>
Moldy buildings started to appear in Europe the 1980ies

- In early 1980ies, studies and management efforts of the problem in Scandinavia, GB and Netherlands
- Results of extensive population studies were reported; consulting needs increased due to individual cases
- In 1990ies, active research on the problem e.g. in Denmark and Finland
- Today, awareness good in Northern and mid-Europe, less attention in Mediterranean region
- No EU regulations or guidelines; IAQ working groups in action
NAS Institute of Medicine: Damp Indoor Spaces and Health (2004)

- Extensive and thorough evaluation of literature on moisture, exposure, toxicological aspects, prevention and remediation
- Summary of the health effects linked with damp indoor environments
- Existence of problem identified, still many open issues
Dampness and mould – WHO Guidelines for indoor air quality (2009)

• Includes an extensive background review of literature
• Conclusion: dampness and mold harmful, should be prevented
• Qualitative guidance for ventilation and control of moisture and mold
• No numerical guideline values for biological agents
• More specific regional and national guidance recommended
• can be loaded at www.who.int
EU working groups on IAQ

ELEVATED COLLABORATIVE ACTION
INDOOR AIR QUALITY & ITS IMPACT ON MAN
Environment and Quality of Life
Report No. 12
Biological Particles in Indoor Environments

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Brussels, 02.-03.12.2010; Prof. Aino Nevalainen
WHO practical guides for IAQ
Canadian guide for fungal contamination

Fungal Contamination in Public Buildings: Health Effects and Investigation Methods

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Other countries have given guidance

- Mold guidance follows similar logics everywhere
- No health based numerical TLVs
- Qualitative guidance for elimination and prevention of mold
"Have molds turned more harmful than before?"

- Molds have always been there – much before us
- Molds and bacteria have the genetic capacity to produce harmful metabolites once it is needed e.g. to keep a niche or habitat
- Secondary metabolism regulated by conditions
- Modern buildings provide niches that favor certain organisms and induce them to produce toxic metabolites
- Modern indoor environments have their own microbial ecology that is not yet fully understood
Use of buildings has changed

- Modern lifestyles:
  - Use of water increased: laundry, showering
  - Water and sewage piping in every household
  - Maintenance of buildings decreased?
  - Complex architecture and constructions, complex moisture control
  - Tight buildings -> more exposure

NATIONAL INSTITUTE FOR HEALTH AND WELFARE
Part 2: History
Thursday, August 30
8:00 – 8:45 a.m.
Bioaerosols History: Tennessee Building; Autumn 1981

- First air conditioned building in Tennessee (1930s)
- Air washer system
- Three outbreaks of humidifier; each associated with activation of water sump-air washer system.
Tennessee Building (Continued)

- April 1981. Client occupies building; AC on
- September 18, 1981. AC system turned off; Stagnant water in sumps increases to room temperature
- September 21, 1981. AC system turned on; First outbreak of HP occurs as warm water used in air-washer system.
Three outbreaks of acute HP occurred; Outbreaks occurred after AC system with stagnant, warm (70° - 80°F) water turned on.

Building was vacated after third outbreak of acute HP.
Tennessee Building (Continued)

- Slime observed on baffle plates of both air-washer systems
- Slime on decking of AC units and floor of MER
- Numerous fungi, bacteria, protozoa and nematodes found in “Slimes”
Tennessee Building: What Did I Learn?

- The qualitative inspection was more useful than sampling
- Operate the HVAC system correctly
- Listen to the HVAC engineer; when the dew point temperature and the dry bulb temperature are about equal (e.g., both at about 72°F), you have indoor cloud formation and a great opportunity for microbial growth.
MICROBIAL SLIME

Photo Courtesy of Philip Morey
A. Repair all external and internal leaks promptly and permanently
B. Eliminate the use of water spray systems
C. Remove stagnant water and slimes from building mechanical systems
D. Use steam as a moisture source in humidifiers
E. Relative humidity in occupied spaces and in low velocity plenums should not exceed 70%
F. Discard microbially damaged materials
   • Porous contents that are contaminated: Better to discard; do not attempt disinfection
   • Dirty insulation on HVAC airstream surfaces should be discarded
   • Minimize aerosolization of respirable particulate during clean-up
Bioaerosols History: AIA Symposium; November 9, 1984

G. Use filters with a 50% rated efficiency (dust spot); air cleaners should not emit ozone into HVAC airstream

H. Provide at least 20 and 5 CFM of outdoor air per occupant for smoking and non-smoking environments, respectively
Bioaerosols History: ACGIH Committee; April 1986

- Remedial actions include the following: Remove biofilms, do not use cool mist vaporizers, keep indoor RH below 70% and discard porous building materials visually contaminated with fungi
- Additional samples should be taken to document if remedial actions were effective
Bioaerosols History: ACGIH Committee; April 1986

• Sampling Strategy: Identify the source of selected airborne microorganisms so that effective corrective actions may be undertaken
• Data Interpretation: If the total count in the affected person’s area exceeds 10,000 per $M^3$, proceed to remedial actions

Applied Industrial Hygiene, 1986 R-19 to R-23
Bioaerosols History: ACGIH Committee; Sept. 1987

- Emphasis was still on sampling. In cases where positive evidence exists for diseases related to biologic contamination (HP, allergic asthma) – Bioaerosols sampling should be undertaken
- The 10,000 total count per M³ is gone

Applied Industrial Hygiene, 1987 R-10 to R-16
Bioaerosols History: ACGIH Committee; Sept. 1987

- Data interpretation. There are no published standards of risk associated with exposure to saprophytic bioaerosols
- Rank order assessment recommended as method to evaluate contribution of outdoor air to indoor bioaerosols
- Still – too much emphasis on sampling.

• See Hodgson et al., Journal of Occupational Env. Health 40, 241-249, 1998
The Florida Courthouses: What Did We Learn?

ONE PROBLEM

- Low permeance vinyl wall covering placed on inside surface of exterior wall in air-conditioned building in warm, humid climate.
- Moisture migrates from humid outdoor air into envelope wall. Especially if building is negatively pressurized to outdoor air.
- Condensation and mold growth occur at vinyl wall-covered surface.

Photo Courtesy of Philip Morey
Exposures in rooms where moldy VWC occurs:

- At times, exposures can be $10^2$ to $10^3$ cfu/m$^3$
- Mostly keratolent nanophylloplane species
  - Aspergillus and Penicillium species

Photo Courtesy of Philip Morey
Bioaerosols History: What Else Did We Learn?

This courthouse contained about 20,000 M² of visible mold, much of which was hidden.
Bioaerosols History: What Else Did We Learn in the Florida Courthouses?

Containment of remediation dusts is essential

Photo Courtesy of Philip Morey
Bioaerosols History: What Else Did We Learn in the Florida Courthouses?

HEPA Vacuum cleaning is essential to remove surface (residual) dusts