# 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- Historical documents exist: people have always known that mold is harmful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

- Richards (1954). Atmospheric mold spores in and out of doors. J Allergy 25:429-439
  - 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

- Lidwell and WC Noble (1975). Fungi and Clostridia in hospital air: the effect of air-conditioning.
  - Fewer fungi in air-conditioned hospital
  - In naturally ventilated hospitals: fungi originate from outdoors, bacteria from humans
- Hirsch et al. (1978). Effect of central air-conditioning and meteorological factors on indoor spore counts. JACI 62(1):22-26.
  - Lower counts and lower RH in air-conditioned homes
- Ager and Tickner (1983). The control of microbiological hazards associated with air-conditioning and ventilation systems. Ann occup Hyg 27(4):341-358.

# 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

## Important moulds causing occupational respiratory allergy (Gravesen et al. 1994)

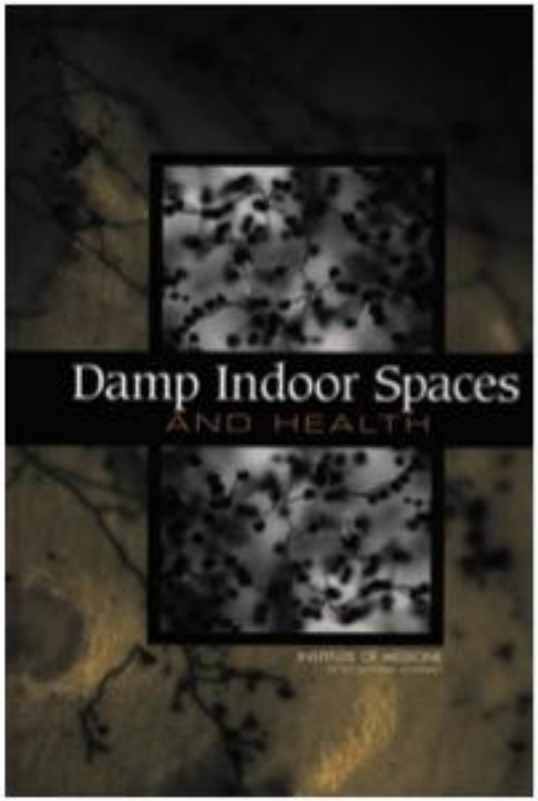
| Allergen source | Environmental exposure | Disease |
|---|---|---|
| *Alternaria alternata* | mouldy logs | wood pulp-worker's lung |
| *Aspergillus clavatus* | mouldy malt | malt worker's lung |
| *A. fumigatus* | mouldy wood chips<br>mouldy sphagnum | wood chip burner's lung<br>greenhouse lung |
| *A. niger* | enzyme | asthma |
| *A. oryzae* | acid production | asthma |
| *Botrytis cinerea* | mouldy plants | asthma, greenhouse lung |
| *Eurotium rubrum*<br>*(Aspergillus umbrosus)* | mouldy hay | farmer's lung |
| *Penicillium camemberti* | cheese production | asthma, cheese worker's lung |
| *P. Communae* | mouldy cheese | cheese worker's lung |
| *P. Roqueforti* | cheese production | asthma, cheese worker's lung |
| *Rhizopus stolonifer* | sawmills | wood trimmer's disease |
| *Scopulariopsis brevicaulis* | mouldy tobacco | tobacco worker's disease |
| Mixed mould populations | ventilation ducts<br>mouldy garbage and<br>compost for recycling humidifiers | waste-handling disease<br>humidifier disease |

# 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 Nothern and mid-Europe, less attention in Mediterranean region
- No EU regulations or guidelines; IAQ working groups in action

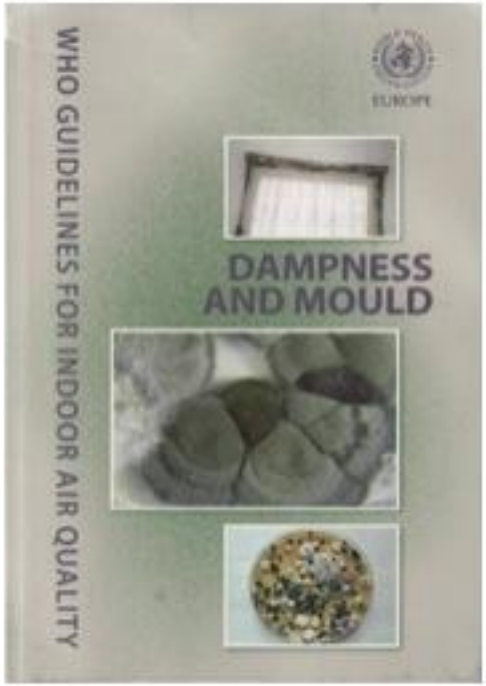
# NAS Institute of Medicine: Damp Indoor Spaces and Health (2004)

- 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



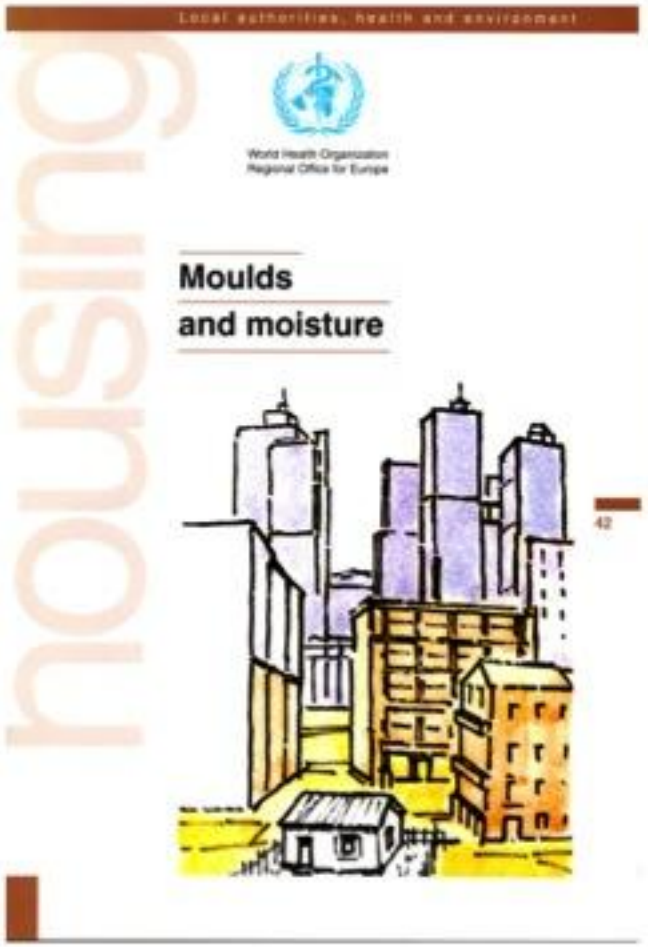
# Dampness and mould – WHO Guidelines for indoor air quality (2009)

- 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

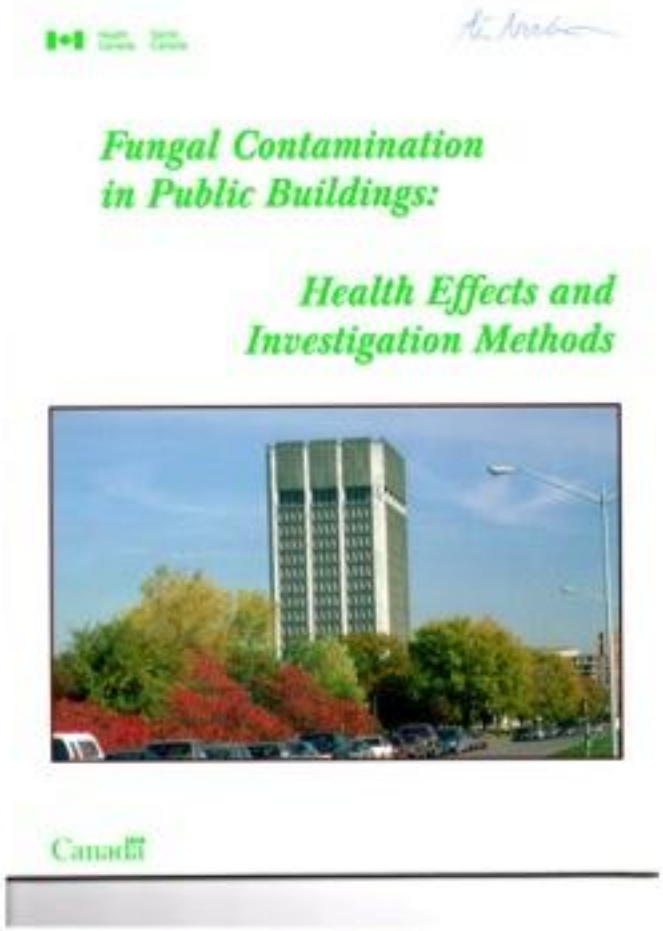


# EU working groups on IAQ

# WHO practical guides for IAQ



# Canadian guide for fungal contamination



# 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
- Seconday 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

# 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.

# Tennessee Building (Continued)

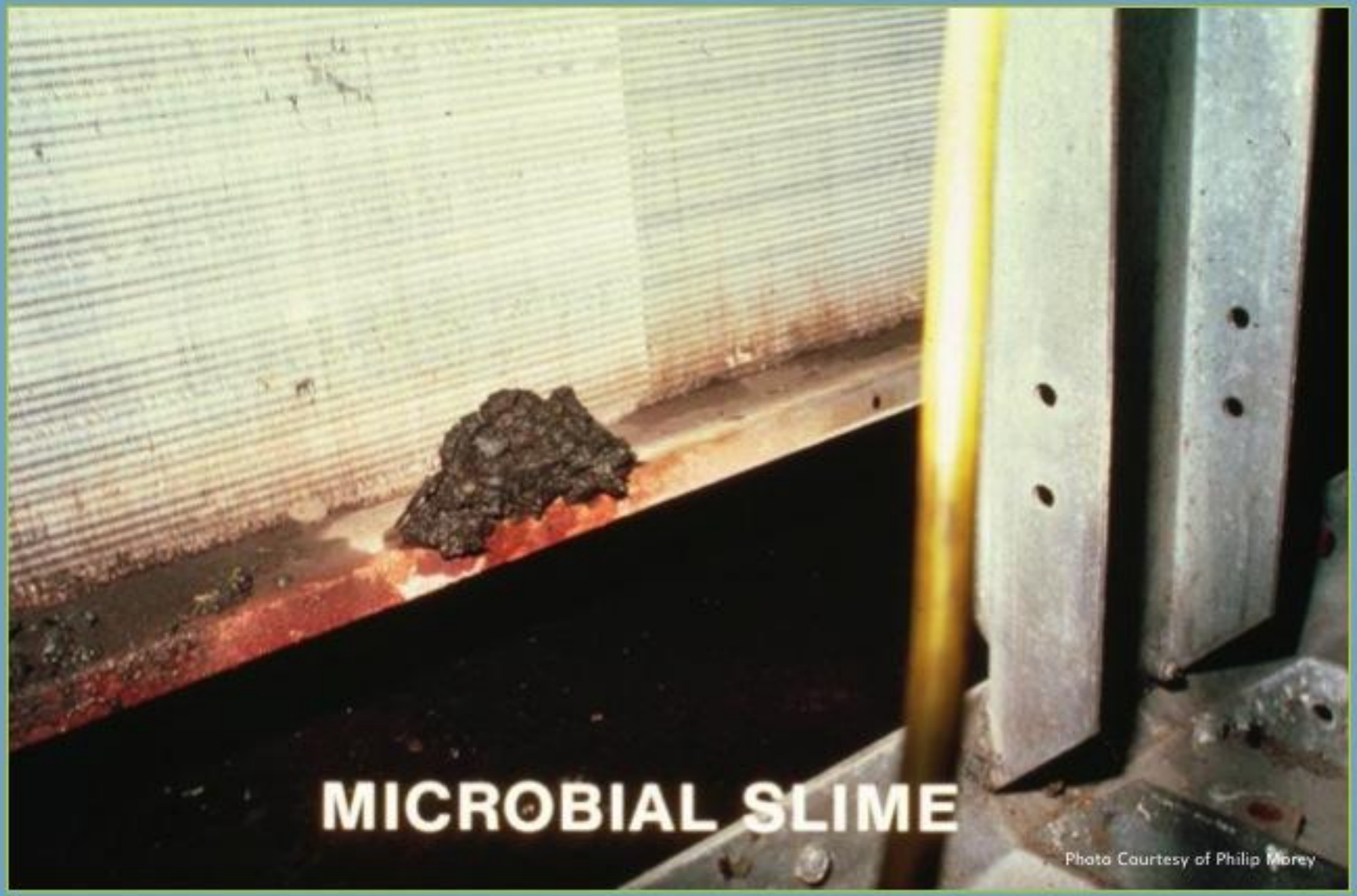
- Three outbreaks of acute HP occurred; Outbreaks occurred after AC system with stagnant, warm (70° - 80°F) water turned on
- Building was vacated after third outbreak of acute HP

# 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

# Bioaerosols History: AIA Symposium; San Francisco November 9, 1984; Engineering Preventive Measures

A. Repair all external and internal leaks promptly and permanently
B. Eliminate the use of water spray systems

## Bioaerosols History: AIA Symposium; November 9, 1984

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%

## Bioaerosols History: AIA Symposium; November 9, 1984

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

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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 $M^3$ is gone

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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.

# Bioaerosols History: The Florida Courthouses, 1991-1996

- See Jarvis & Morey, Applied Occupational & Env. Hyg., 16, 380-388, 2001
- 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

# The Florida Courthouses: What Did We Learn?

# Bioaerosols History: What Else Did We Learn?


This courthouse contained about 20,000 $M^2$ 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

# Bioaerosols History: What Else Did We Learn in the Florida Courthouses?


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