

# Indoor air quality, fungi, and health

## *How do we stand?*

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### ABSTRACT

**OBJECTIVE** To equip medical practitioners with up-to-date scientific and medical information on the health effects of exposure to fungi in indoor air, clinical evaluation of these health problems, and possible preventive measures.

**QUALITY OF EVIDENCE** MEDLINE was searched from 1985 to 2000 using the MeSH words mould (mold), fungus, indoor air, and health effects. Nearly all studies were case reports, case-control studies, and cross-sectional studies. Evidence of an association between respiratory problems and the presence of fungi and dampness is strong.

**MAIN MESSAGE** Recent well designed studies and literature reviews indicate that exposure to dampness and fungi in indoor air brings on or exacerbates asthma and other respiratory complaints. More studies are required, however, before a definite conclusion on other potential effects of such exposure (such as systemic and long-term effects and pulmonary hemorrhage in infants) is possible. The various health problems that can result from exposure to dampness and fungi in indoor air make such exposure unacceptable from a public health perspective. Physicians are important in treating and preventing such problems; various resources are available to help them.

**CONCLUSION** Even though some scientific issues remain to be resolved concerning the health effects of exposure to dampness and fungi in indoor air, family physicians can identify potential problems and refer patients to appropriate resources.

### RÉSUMÉ

**OBJECTIF** Présenter aux praticiens de la médecine les renseignements scientifiques et médicaux les plus récents concernant les effets sur la santé de l'exposition aux moisissures dans l'air ambiant; l'évaluation clinique de ces problèmes de santé et les mesures de prévention possibles.

**QUALITÉ DES DONNÉES** Une recension a été effectuée dans MEDLINE de 1985 à 2000 à l'aide des termes MeSH en anglais pour moisissures, champignons, air ambiant et effets sur la santé. Presque toutes les études étaient des rapports de cas, des études de cas contrôlées et des études transversales. Des données probantes font une étroite association entre les problèmes respiratoires et la présence de champignons et d'humidité.

**PRINCIPAL MESSAGE** L'analyse de récentes études bien conçues et des ouvrages scientifiques fait valoir que l'exposition à l'humidité et aux champignons dans l'air ambiant déclenche ou exacerbe l'asthme et d'autres problèmes respiratoires. Par ailleurs, un plus grand nombre d'études est nécessaire pour déterminer de manière absolue la possibilité d'autres effets potentiels d'une telle exposition (comme des effets systémiques et à long terme et l'hémorragie pulmonaire chez les nourrissons). Les divers problèmes de santé qui peuvent résulter de l'humidité et des champignons dans l'air ambiant font d'une telle exposition un facteur inacceptable du point de vue de la santé publique. Les médecins jouent un rôle important dans le traitement et la prévention de tels problèmes; diverses ressources sont à leur disposition pour les aider.

**CONCLUSION** Même s'il reste certaines questions scientifiques à résoudre concernant les effets sur la santé de l'exposition à l'humidité et aux champignons dans l'air ambiant, les médecins de famille peuvent identifier les problèmes potentiels et aiguiller les patients vers les ressources appropriées.

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*Cet article a fait l'objet d'une évaluation externe.*

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**T**he air we breathe is essential for life, yet at the same time it is a potential source of contaminants associated with disease. Today's medical practitioners are often confronted with patients who are exposed to myriad contaminants (often present at low levels) in their indoor environments at home, at school, or in the workplace.

With time, the focus of attention has shifted from problems of inadequate ventilation to microbial contamination of indoor air; up to half the current indoor air-quality cases investigated by the National Institute for Occupational Safety and Health (NIOSH) in the United States concern microbial contamination.<sup>1</sup>

This article aims to update current scientific knowledge concerning the health effects of exposure to fungi in indoor air, since most complaints with microbial contamination of indoor air involve this type of microorganism. Preventive measures, physicians' role, and resources that can be helpful will also be discussed.

### Quality of evidence

This article is based on a MEDLINE search from 1985 to 2000. MeSH words used were mould (mold), fungus, indoor air, and health effects. Studies that attempted to control for confounding variables and that relied on at least some objective measures of exposure or outcome were given priority. Recent review articles and consensus reports were also consulted.

Several studies on how exposure to fungi in indoor air affects health have been published over the past two decades, the vast majority of which are case reports and case-control and cross-sectional studies. Because moisture is crucial to mold growth, many of these studies also examined the effects of dampness; it is often difficult to dissociate these two factors. Other problems with epidemiologic studies dealing with exposure to mold in indoor air include difficulty in quantifying exposures; difficulty in identifying precise outcome measures; and presence of confounding variables, such as tobacco smoke and pets.<sup>2,3</sup>

The recent publication of well designed studies and comprehensive literature reviews suggests a causal relationship between exposure to mold or dampness indoors and development or exacerbation of respiratory symptoms and asthma.<sup>4-15</sup>

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### Fungi in indoor air

**Where do they come from?** The fungi that affect indoor air quality are multicellular organisms formed of microscopic branched filaments called hyphae. A visible colony of interwoven hyphae forms a mycelium, and the mycelioid fungi most commonly found indoors are called molds<sup>12</sup>; the terms fungus and mold will be used interchangeably in this article.

When windows can be kept open, the kind of fungi in indoor air normally reflect those in outdoor air.<sup>9</sup> To grow and proliferate indoors, however, fungi require a suitable substrate (wood, paper, gypsum board, or other materials that have a high cellulose content) and water. Buildings where there is chronic water damage or where humidity levels are high are particularly at risk of fungal contamination.<sup>10,12</sup>

Allergenic molds that grow indoors include species from the *Penicillium* and *Aspergillus* genera. When humidity is excessive or water damage exists, *Stachybotrys chartarum* (formerly known as *Stachybotrys atra*), *Fusarium*, *Trichoderma*, and others can grow.<sup>10,11</sup>

Several authors have tried to estimate the prevalence of homes with high humidity levels and mold growth. Estimates vary from 14% to 66%.<sup>6,14-16</sup>

**How do indoor fungi affect health?** Various aspects of fungal growth and structure can explain potential effects on health. Certain species of fungi produce mycotoxins, natural organic compounds that initiate a toxic response in humans (mucosal and skin irritation, immunosuppression, and systemic effects).<sup>7,11,13</sup> The primary mode of human exposure to these toxic chemicals is by inhalation of spores or of material that has been contaminated by mold.<sup>7,12</sup>

Molds also produce various volatile organic compounds, such as alcohols and ketones, during their growth cycle. These compounds, which are responsible for the musty odour associated with the presence of molds, are irritants, as are glucosans (a component of fungal cell walls).<sup>7,11,12</sup>

Certain species of fungi can cause infectious diseases, but this is rare, unless the exposed person is severely immunosuppressed (eg, bone marrow transplant patients).<sup>7</sup>

Susceptible hosts can also develop allergies, such as rhinitis and asthma, when exposed to molds.<sup>10</sup> Heavy and repeated exposure to small fungal particles can also cause hypersensitivity pneumonitis in certain people.<sup>12</sup>

## CME

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### Indoor air quality, fungi, and health

**Respiratory problems.** Studies designed to account for methodologic difficulties described earlier have been carried out to evaluate which health effects can be attributed to exposure to mold. For example, Brunekreef and colleagues<sup>4</sup> found a consistent association between dampness and molds in the home and childhood respiratory problems, such as wheezing, cough, or chest illness, after adjusting for city of residence, maternal smoking, age, sex, and parental education. Odds ratios varied from 1.23 to 2.26, and all but one were statistically significant.<sup>4</sup> More recently, Dales and Miller<sup>5</sup> conducted a study of 403 Canadian schoolchildren in which they examined health effects of exposure to mold. Mold exposure was evaluated subjectively, but the analysis accounted for several confounding variables, such as presence of smokers or pets in the home, parental allergies, and presence of bacterial endotoxin and dust mite antigens in air and dust samples.<sup>5</sup> The resulting adjusted odds ratios for mold exposure varied from 1.51 to 2.25 for various symptoms (systemic illness, irritation, cough or wheeze, chest illness).

It should be noted that Dales and Miller<sup>5</sup> did not find a positive relationship between presence of mold and asthma diagnosed by a physician. Williamson and colleagues addressed this particular issue by comparing patients from an asthma clinic with control subjects matched for age (between 5 and 44 years) and sex.<sup>6</sup> The authors also developed an asthma severity score. Finally, dampness and mold growth were evaluated objectively by a qualified surveyor who was blinded to the health status of the study subjects. Confounding variables controlled for included employment status, household income, active and passive smoking, and pets.

The results of the study by Williamson and associates<sup>6</sup> showed that asthmatic patients attending a hospital clinic were two to three times more likely to live in a home with evidence of dampness than a control group matched for age and sex. The odds ratio was 1.70 for presence of noticeable mold. The authors also observed a dose-response relationship between damp housing and asthma severity, but they did not control for presence of house dust mites, also a known cause of asthma, that thrive in humid conditions. They were thus unable to conclude whether mold acts as a marker for home dampness, which causes asthma, or whether mold is the actual cause of this disease.

Finally, results of the case-control study conducted by Verhoeff and colleagues<sup>17</sup> suggest that sensitization to dust mites and possibly to mold allergen is

important in the relationship between living in a damp home and childhood respiratory symptoms.

**Other health problems.** Systemic effects, such as headache, fever, excessive fatigue, cognitive and neuropsychological effects, gastrointestinal symptoms, and joint pain, have also been observed in certain groups exposed to molds. These effects have been less well documented, and their importance is not always clearly established. The potential cause remains unknown, which means that further studies on systemic effects of mold exposure are required.<sup>7,8</sup> The same is true for potential long-term effects (chronic obstructive lung disease, cancer) for which an association has not yet been established.<sup>1,5,9-11,13</sup>

Symptoms caused by exposure to mold should disappear once exposure ceases. The proportion of exposed people who will have adverse health effects in various exposure circumstances has not been clearly established; certain groups do show greater susceptibility to the toxic effects of mold exposure (children, people with certain diseases or who are immunosuppressed, atopic patients, etc). Whether there is a threshold for exposure below which no health effects occur is unknown.<sup>7,11</sup>

**Pulmonary hemorrhage in infants.** During the mid-1990s, a series of publications associated exposure to dampness and molds (particularly *S chartarum*) in homes in Cleveland, Ohio, with an outbreak of pulmonary hemorrhage and hemosiderosis in infants<sup>18,19</sup>; however, presence of tobacco smoke in the homes of most of the sick children was an important confounding factor.

A *Morbidity and Mortality Weekly Report* update concludes that various shortcomings in the initial Centers for Disease Control investigation prevent considering *S chartarum* as a cause of acute idiopathic pulmonary hemosiderosis.<sup>20</sup> Continuing publication of new case reports suggests that this issue is still not fully resolved,<sup>21-23</sup> and recently updated guidelines concerning exposure to indoor fungi affirm that infants diagnosed with pulmonary hemosiderosis or pulmonary hemorrhage should not be returned to damp or moldy dwellings until remediation and air testing are completed.<sup>11</sup>

**What can be done?** It is clear that exposure to dampness and mold indoors is unacceptable from a public health perspective<sup>24</sup> and that mold, water damage, and musty odours should be investigated immediately.<sup>11,12</sup>

Certain measures can prevent exposure to molds. Because moisture must be available for fungal growth,

the most obvious measure is to control humidity levels according to Canada Mortgage and Housing Corporation guidelines.

Another important measure is to ensure that any building defects that allow water damage or water infiltration are repaired as soon as possible to prevent proliferation of molds. Finally, if fungal growth has occurred, protocols have been developed for cleaning up contamination safely.<sup>11</sup>

### What is physicians' role?

Physicians must be aware that the indoor environment can explain persistence of a health problem *that does not respond to traditional treatment*. When such a situation is suspected, physicians should investigate the problem by means of a comprehensive questionnaire and physical examination (Table 1<sup>11,25</sup>), thus enabling them to evaluate their patients' medical histories, previous exposures, possible sources of exposure to mold and dampness, and current health problems. It is particularly important to note that disappearance or diminishing of symptoms when not exposed to a potentially contaminated environment is key to determining the origin of reported health problems.

### What resources are available?

It is important for family practitioners to be aware of specialized resources in environmental and occupational health. In Quebec, for example, public health is very active in these fields. Physicians treating patients suffering from health problems potentially caused by exposure to fungi in indoor air should contact local public health departments to obtain any support they can offer.

Another valuable source of information is the Canada Mortgage and Housing Corporation, which has offices throughout Canada and has published many practical guides designed to help solve problems caused by excessive moisture, water infiltration, and fungal contamination. Websites of other pertinent sources of information are presented in Table 1.<sup>11,25</sup>

### Conclusion

At present, the respiratory effects of exposure to mold and dampness are well documented. Further studies are required to establish a causal relationship between exposure to mold and systemic effects, such as headache, fever, excessive fatigue, and neuropsychological changes. Family physicians are key to identifying any health problems caused by exposure to these contaminants and to

**Table 1. Checklist for physicians investigating health problems potentially related to mold indoors**

ELEMENTS OF EXAMINATION	IMPORTANT FINDINGS
Medical history and previous exposures	Atopy: familial and personal* Presence of chronic diseases Habits: tobacco, alcohol, etc Occupational exposures: dust, solvents, etc
Symptom questionnaire†	Allergic symptoms: respiratory Irritative symptoms: eyes, nose, throat, upper airways Recurrent infections: otitis, sinusitis Fatigue, lack of energy Skin problems Cognitive problems
Environmental history	History of water infiltration, leaks, or other water damage Presence of visible molds Condensation on windows, walls, or other structures Musty odours Complaints from other occupants of the same environment
Physical examination	Evaluate for <ul style="list-style-type: none"> <li>• rhinitis</li> <li>• asthma</li> <li>• sinusitis</li> <li>• otitis</li> <li>• skin disease</li> </ul>
Resources	Medical specialists: pulmonary, otolaryngology, dermatology, environmental medicine Public health department Websites: <ul style="list-style-type: none"> <li>• Canadian Mortgage and Housing Corporation (<a href="http://www.cmhc-schl.gc.ca">www.cmhc-schl.gc.ca</a>)</li> <li>• New York City Department of Health (<a href="http://www.ci.nyc.ny.us/html/doh/html/epi/moldrpt1.html">http://www.ci.nyc.ny.us/html/doh/html/epi/moldrpt1.html</a>)</li> <li>• McMaster Institute of Environmental Health (<a href="http://www.mcmaster.ca/mieh/furpt.htm">http://www.mcmaster.ca/mieh/furpt.htm</a>)</li> </ul>

\*Skin tests can be carried out to establish patients' atopy with respect to molds. Because exposure to fungi routinely occurs both indoors and outdoors, however, this information is of limited value.<sup>11</sup> In addition, molds common in Canadian homes do not correspond to the extracts of fungal species available from major companies for allergy testing.<sup>25</sup>

†Symptoms that do not respond to traditional treatment or that disappear with cessation of exposure suggest that indoor environments are important in their etiology.

referring patients to appropriate specialists who can help them eliminate sources of dampness and mold in their environments. ❁

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### Editor's key points

- Many studies have shown an association between respiratory problems and the presence of dampness and fungi in buildings. More studies are needed to establish whether other symptoms are brought on by exposure to these contaminants.
- Disappearance of symptoms when people are no longer exposed to dampness and fungi is an important factor in establishing whether exposure to these contaminants is associated with health problems.

### Points de repère du rédacteur

- Plusieurs études ont montré une relation entre les problèmes respiratoires et la présence de moisissures et de conditions humides dans les édifices. Des études additionnelles sont nécessaires pour établir s'il y a une association entre d'autres symptômes généraux et l'exposition à ces substances.
- La disparition des symptômes lorsque la personne n'est pas exposée aux moisissures et aux conditions humides est un élément important pour établir un lien entre l'exposition à ces agents et la présence d'un problème de santé.

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