

**INDOOR AIR POLLUTANTS IN RESIDENTIAL SETTINGS:
Respiratory Health Effects and
Remedial Measures to Minimize Exposure**

A Review for The Ontario Lung Association

by Bruce M. Small, P.Eng.
Small and Fleming Limited
Research Consultants in Environmental Health

April, 2002
(Rev. 12Apr2002-1130)

Indoor Air Pollutants in Residential Settings

Acknowledgments

The Ontario Lung Association wishes to acknowledge and thank the following:

**Dr. Alan Abelsohn
Dr. Karen Bartlett
Dr. Robert Dales
Dr. Judy Leech
Ian Morton**

for reviewing earlier drafts of the health section of this report;

and



The Laidlaw Foundation

For its generous financial support of this initiative.

Indoor Air Pollutants in Residential Settings

Table of Contents

<i>Report Summary</i>	3
1 Introduction and Purpose of this Report	6
2 Evidence and Gaps in Understanding	7
2.1 Overview	7
2.2 Effects of Indoor Contaminants on Respiratory Health	8
2.3 Contaminants and Conditions of Concern in Indoor Air	9
2.3.1. Dampness	9
2.3.2. Mould	13
2.3.3. Bacteria	24
2.3.4. Viruses	28
2.3.5. Dust Mites	31
2.3.6. Insects / Cockroaches	35
2.3.7. Animal Dander	37
2.3.8. Environmental Tobacco Smoke	40
2.3.9. Other Products of Combustion	44
2.3.10. Products of Emission	51
2.3.11. Particulate Matter	58
2.3.12. Other Specific Contaminants	63
3. Conclusions	68
4. References	70
 APPENDICES	
1. Brief Background on Specific Respiratory Diseases	83

REPORT SUMMARY

1. Background

The Lung Association commissioned a public perception survey by Environics (July 2001), which reported that the majority of Ontarians expressed the view that indoor air pollution was a relatively minor problem compared to outdoor pollution. Given that concentrations of indoor pollutants can sometimes greatly exceed outdoor concentrations, The Lung Association then commissioned a report to provide an overview of current research into the respiratory health effects of common indoor air pollutants. Prepared by Mr. Bruce M. Small, P.Eng., of Small and Fleming Limited, the report was reviewed by a panel of individuals with demonstrated expertise in the field of indoor air quality and human health. Financial support for both initiatives was provided by the Laidlaw Foundation.

Each indoor contaminant was assessed individually from a respiratory health perspective. They vary widely in their nature, their potential respiratory effects, the degree of risk, the quality of evidence supporting the potential connection between exposure and health effects, and the means of remediating indoor environments to reduce or avoid exposure.

Ample evidence of respiratory risk was found to support continued action and education concerning reduction of indoor pollutants. The respiratory health risks associated with the indoor air contaminants examined include respiratory symptoms (such as rhinitis, sore throat, hoarseness, cough, phlegm, tight chest, difficult breathing and wheezing), airway irritation, respiratory infections, asthma, airway inflammation, bronchitis, emphysema, reduced lung function, idiopathic pulmonary haemorrhage, hypersensitivity pneumonitis and lung cancer.

2. Highlights

Dampness and Mould

Dampness in housing is associated with airway inflammation, exacerbation of asthma, increased incidence of wheezing and other respiratory symptoms, and increased incidence of upper respiratory infections. Excess moisture, high humidity and water leakage often lead to the growth of mould. Mould has been associated with the same list of adverse respiratory health effects as for dampness, as well as changes in lung function, e.g. increased peak flow variability, and development of allergy to mould.

Mould appears to exacerbate respiratory conditions both directly (e.g. exacerbation of existing asthma) and indirectly (e.g. increased incidence of colds and increased sensitization). Toxic mould has also been present and implicated in some cases of idiopathic pulmonary haemorrhage, but there remains some controversy over whether the evidence supports a causal connection.

Well-sealed building envelopes, proactive moisture and humidity control, and early remedial action at the first sign of water leakage or dampness in housing are the primary means of preventing subsequent mould growth and reducing the risk of respiratory effects. Complete removal of mouldy material is required once mould growth has taken place.

Bacteria

Bacteria can be found indoors in situations where there is water damage, dampness, or warm standing water (e.g. in humidifier trays or in the condensate from air conditioning coils). Evidence suggests an association between bacteria or bacterial endotoxin exposure in housing and increased incidence of upper respiratory infections, increased incidence of respiratory symptoms, (including cough and difficulty breathing), airway inflammation, exacerbation of asthma, chronic bronchitis, emphysema and

hypersensitivity pneumonia. The environmental remedies are the same as for dampness, plus attention to standing water in humidifiers and air conditioners.

Viruses

Airborne viruses can be transmitted from person to person indoors, particularly where fresh air ventilation is inadequate. Infectious organisms can be atomized by coughing, sneezing, singing and even talking. Evidence suggests adverse respiratory effects such as airway inflammation, decreased lung function and exacerbation of asthma, particularly by rhinoviruses. Development of specific childhood diseases such as measles is also cited as a risk. The spread of viruses indoors can be minimized by careful attention to personal hygiene (particularly handwashing). Fresh air ventilation can also dilute airborne viruses in the presence of infected individuals.

Dust Mites, Cockroach Antigen and Animal Dander

In addition to exacerbating asthma and decreasing lung function, dust mites may play a causative role in the development of asthma. Exposure to insects and cockroaches antigens has been also linked to exacerbation of asthma, decreased lung function and respiratory allergy. Animal dander exposure is associated with exacerbation of asthma and sensitization to the allergen.

Maintaining indoor humidity below 50% and encasement of mattresses with moisture-impermeable covers will minimize dust mite exposure. Other measures include frequent vacuuming, reduction of clutter, and if necessary, removal of carpets and drapes. Maintaining kitchen hygiene and proper housekeeping can reduce the chance of cockroach infestation. In some cases, removal of pets from the home may be necessary. If this is not practical, more frequent housekeeping and pet-free zones for allergic individuals will reduce exposure.

Environmental Tobacco Smoke (ETS)

ETS exposure is associated with a number of adverse respiratory health outcomes, including increased frequency of lower respiratory tract illnesses in infants and a reduced rate of lung function growth in childhood. In addition to exacerbation of existing asthma, ETS may also cause asthma through prenatal maternal smoking exposure. There is an increased risk of lung cancer in non-smokers who live with smokers. Cessation of all indoor smoking behaviour is the most effective way of avoiding ETS exposure in the home.

Products of Combustion

Emissions from burning wood, gas, oil, kerosene, propane and candles can result in elevated concentrations of potent contaminants including aldehydes, polycyclic aromatic hydrocarbons and carbon monoxide. Respiratory effects can include exacerbation of asthma, increased respiratory symptoms, decreased lung function, lung cancer, and in the case of carbon monoxide, death. Proper maintenance and operation of combustion appliances such as furnaces, stoves, fireplaces and heaters is essential to ensure complete fuel combustion. Adequate fresh air supply is necessary to avoid back-drafting. Installation of appropriate carbon monoxide and smoke detectors will alert occupants to combustion leakage problems. Sensitive individuals may need to consider increasing ventilation over a gas kitchen range, or replacing it with an electric range.

Products of Emission

This category includes gases (e.g. volatile organic compounds, including formaldehyde) and particles emitted from building materials, furnishings, appliances, clothing and products used in cleaning and

personal hygiene. Respiratory effects include wheezing, coughing, decreased lung function, irritation of the upper respiratory tract, airway inflammation, exacerbation of asthma, increase in the risk of pneumonia in children, and, in the case of benzene, risk of lung cancer. Choosing low-emission products and ensuring adequate ventilation can reduce these pollutants.

Radon

Radon, a radioactive component of soil gas that can enter the home through cracks in basement walls and foundations, is linked strongly with lung cancer. Sealing of foundation cracks and other points of entry will reduce concentrations. Subslab ventilation is sometimes required.

Pesticides

Pesticides (from sprays, deodorizers, pest control strips) have been more extensively studied in the occupational environment, such as farming. In this setting, there is a potential association between some pesticide exposures and asthma. Some municipalities have enacted bylaws restricting their use outdoors. Proper indoor hygiene can reduce the need for pesticide use.

Particulate Matter

Much of the data on health effects due to particulate exposure is related to particulates and other air pollutants found outdoors. There is strong evidence linking outdoor PM₁₀ and PM_{2.5} particulates to an increase in respiratory symptoms, episodes of asthma, and respiratory and cardiac mortality. Evidence suggests that there is also an association between exposure to indoor particulates and exacerbation of asthma, inflammation of the airways and increase in the allergic immune response

Indoor air particles can be reduced by aggressive dust control programs, which may include removing curtains and carpeting. One of the most effective strategies to avoid health effects from particulates found indoors is to reduce the hazardous content of airborne and deposited household dust by following measures discussed earlier with respect to other specific indoor contaminants. Some households also maintain a “no shoes” policy to ensure that outdoor particulates from soil and road dust do not get tracked throughout a home.

3. Conclusions

While more evidence is needed to confirm all the causal links between specific indoor contaminant exposures and specific adverse respiratory health symptoms, it is still very clear that reducing unnecessary exposures from indoor contaminants can reduce the risk of negative respiratory health consequences.

Many simple and practical measures can be implemented by home occupants to improve their indoor environment, including moisture and humidity control, elimination of dampness and water leakage, mould removal, sealing of soil gas entry points, reduction of allergen exposures, cessation of smoking, proper maintenance and ventilation for combustion appliances, use of low-emission household products, aggressive dust control and adequate fresh air ventilation.

Information in the report will guide The Lung Association in further development of consumer materials in its C.A.N. DO program. Methods of enhancing awareness of these issues among health care providers will also be explored.

The Lung Association acknowledges and thanks the Laidlaw Foundation for its generous financial support of both the Health Report and the Perception Survey.

1 Introduction and Purpose of this Report

The Ontario Lung Association has been a longstanding educator regarding the health of the human lung. Its program “*C.A.N. DO — The Movement for Clean Air Now*” has been instrumental in alerting the population to the possible adverse health effects of indoor air pollutants and to supplying information to householders as to how to minimize their exposure to pollutants in their home.

This report is an update designed to update the Lung Association with an overview of the current understanding of and recent developments in specific indoor air quality issues and the extent to which they are known to present a risk to the respiratory health of the population, primarily in the residential setting.

The Lung Association’s mandate is to improve respiratory health. One of the ways of doing so is to carry on active programs designed to reduce the amount of exposure of the population to known risks to respiratory health. Because knowledge about health risks is never complete, the Ontario Lung Association must also make decisions about how to educate the public about potential lung risks before all the evidence about a particular exposure is beyond debate. Where evidence is not yet conclusive, the organization still chooses to share its knowledge about the potential lung risks with interested consumers and professionals, who may in turn make their own decisions as to whether to take action.

This report is designed to provide enough information to help the Ontario Lung Association make such program decisions. As such, it is not designed to be a scientific or medical education document, nor a prescriptive how-to-manual for consumers. It may, however, be useful to others beyond the Lung Association who must assess their own responsibilities in the field of indoor air quality.

In most cases, adverse respiratory health risks due to indoor contaminants can be reduced or eliminated by simple practical measures that can be taken by individuals, organizations and governmental agencies. We encounter indoor air at home, at school, at work and at play, and no single jurisdictional authority in Canada holds a clear mandate to co-ordinate activity in indoor air quality. It is the Lung Association’s hope that its own indoor air quality programs and the information contained in this report will lead to a reduction in exposure to harmful substances and consequently to better respiratory health for the population.

2 Evidence and Gaps in Understanding

2.1 Overview

The human lung is the most common site of injury by airborne pollutants. (American Lung Association *et al.*, 1994) The evidence in this report supports the general conclusion that many indoor air contaminants can and do pose a risk to human respiratory health, and that appropriate environmental changes to reduce exposure can reduce this risk.

For many contaminants, only *some* people within an exposed population will experience ill effects. Those who are extremely ill may be the first to suffer. However, *all* of the exposed population constitute the “risk group.” Reducing or eliminating risk by making appropriate environmental changes does increase an individual’s chances of staying well or of improving his or her health. And when many people in a risk group make changes, the overall respiratory health of the population improves.

Each indoor contaminant must be assessed individually, since they vary widely in their nature, their potential respiratory effects, the degree of risk, the quality of evidence supporting the potential connection between exposure and health effects, and the means of remediating indoor environments to reduce or avoid exposure.

Since the Lung Association’s focus is on respiratory health, this analysis has focussed on respiratory effects, including asthma, respiratory tract irritation, infections, inflammation, hypersensitivity pneumonitis, pulmonary haemorrhage and lung cancer. For those readers who wish further information on these conditions a brief discussion of some of these effects is also included in Appendix 1.

Exposure is usually to more than one contaminant at a time. In the research cited, some attempts have been made to isolate the effects of an individual contaminant, but this has not always been possible or successful. Where there are known synergistic effects of exposures to multiple contaminants, these have been reported.

The research cited varies widely in terms of the length of exposures that have been assessed. Prolonged exposures could prove significant for some types of respiratory damage, since some respiratory illnesses are known to compound over time.

While there are significant gaps in knowledge, enough is known to justify action to protect people from indoor pollutants. There are many situations entailing high risks (e.g. carbon monoxide poisoning from faulty furnaces) which are easily remediated. There are many other situations where the health payoff of remediation is less certain, but the logic of remediation is still strong (e.g. fixing drainage to avoid water leakage and mould).

2.2 Effects of Indoor Contaminants on Respiratory Health

For each group of contaminants or indoor conditions described in this section, the following have been reviewed:

- .1 nature of the contaminant and its sources*
- .2 selected evidence suggesting adverse respiratory effects*
- .3 summary of selected evidence*
- .4 remedial action to avoid exposure*

Some indoor conditions and contaminants have been discussed individually, and others have been grouped for convenience and to avoid repetition. There is some unavoidable overlap between categories (e.g. combustion products and particulates).

Evidence was selected from comprehensive texts and peer-reviewed literature which appeared to represent current thought on the respiratory risks associated with each indoor contaminant. Where possible, adverse respiratory effects have been grouped by specific disease or condition. Under “*summary of selected evidence*”, a brief statement is given concerning the specific respiratory health effects associated with the indoor contaminant or condition. If there is any medical or scientific consensus about a causal connection, it is also reported.

Where remedial environmental actions are known that will avoid, mitigate or remove the condition or contaminant, these are outlined. (No attempt is made to describe appropriate medical intervention, which may also be required).

In each specific area, other reviews exist which are more complete in scope and more detailed in nature, and where possible these have been listed in the bibliography for the reader to pursue. The discussions below attempt to selectively highlight indoor air quality information that is most relevant to the Lung Association’s current review, and that reflects current research and understanding of each area. The selection of information has been focussed on helping the Lung Association make decisions concerning its ongoing programs, and as such this study was not an attempt to produce a comprehensive scientific review.

2.3 Contaminants and Conditions of Concern in Indoor Air

2.3.1 Dampness

2.3.1.1 *nature of the contaminant and its sources*

- Problems of condensation and dampness in the home are a common complaint in the United Kingdom. Surveys in Scotland and England estimated that between one quarter and one third of homes may be affected to some degree. (Strachan & Sanders, 1989)
- In a Canadian study, Dales *et al.* conducted a questionnaire-based study on the health effects of the indoor environment in 30 Canadian communities, focussing on the association between the respiratory health of young children and home dampness and molds. Molds were reported in 32.4% of the homes surveyed, flooding in 24.1%, and moisture in 14.1%, with an overall prevalence of home dampness or molds of 37.8%,. (Dales *et al.*, 1991b)
- Dampness in homes can result from a number of conditions, including lack of ventilation, building water leakage, high ground water and flooding, persistent rainy weather or high humidity, plumbing leakage, excess moisture-generating activities indoors (e.g. cooking, showering or too many plants), and overcrowding.

2.3.1.2 *selected evidence suggesting adverse respiratory effects*

i) Respiratory Symptoms

- In the Canadian study by Dales and colleagues cited above, 13,495 children were included in the study group. The housing stock was distributed as follows: 81% were one-family detached homes, 6% were one-family attached homes, and 13% were buildings for two or more families. Prevalences of all respiratory symptoms were consistently higher in homes with reported molds or dampness. The adjusted odds ratios ranged from 1.32 (95% confidence interval 1.06-1.39) for bronchitis to 1.89 (95% confidence interval 1.58-2.26) for cough. (Dales *et al.*, 1991b)
- The association between living in damp homes and the prevalence of health symptoms was investigated in a population of 519 occupants (adults and children) of 185 homes in the Netherlands. Positive associations were found between the reporting of respiratory and some other health symptoms and living in a damp house. The concentration of

viable mould spores in indoor air was measured, using modified Andersen samplers, in the living rooms of a sample of 36 homes. The results were compared with the occurrence of dampness characteristics in their homes as reported by the occupants. Homes with at least two dampness characteristics showed higher average spore counts and higher prevalence of respiratory symptoms. (Waegemaekers *et al.*, 1989)

- A study of the possible association between dampness and illness in the United Kingdom revealed an association between reported dampness and cough and wheeze in children. (Strachan & Sanders, 1989)
- In a recent study of the relationship between moisture and respiratory symptoms, exposure to moisture was significantly associated with sinusitis, acute bronchitis, nocturnal cough, nocturnal dyspnea and sore throat. (Koskinen *et al.*, 1999)
- A Finnish study of the effects of moisture damage in a school on children's health showed that the prevalence of respiratory symptoms and infections was higher in the exposed students compared to those in a non-damaged school. All prevalence of respiratory symptoms decreased in the exposed schoolchildren after renovation of the school to remediate the moisture damage. (Savilahti *et al.*, 2000)

ii) Common colds and other respiratory infections

- A questionnaire survey of 10,667 Finnish first year university students aged 18-25 found a positive association between home dampness (reported as visible mould or damp stains or water damage) and incidence of self-reported common colds and other respiratory infections greater than four times per year. Of the respiratory infections, the risk of common colds was most clearly increased. (Kilpelainen *et al.*, 2001)
- Koskinen *et al.* also found that inhabitants exposed to moisture in their homes had significantly more episodes of common cold and tonsillitis. (Koskinen *et al.*, 1999) Bornehag and colleagues (discussed below under asthma) also concluded that there is an association between dampness in buildings and airways infections. (Bornehag *et al.*, 2001) Pirhonen *et al.* found self-reported symptoms of bronchitis and common colds to be strongly associated with living in a damp home. (Pirhonen *et al.*, 1996)

iii) Asthma

- Wever-Hess and colleagues evaluated patients with doctor-diagnosed asthma in a clinical registration study, aged 0-4 years, including a two-year followup period. In the age group 0-1 year, damp housing was a predisposing factor for asthma exacerbation (defined as increases in cough and/or wheeze and/or breathlessness, increase in beta(2)-agonist use, and a clinical need for a short course of oral corticosteroids). The odds ratio was 7.6, with 95% confidence interval of 2.0-28.6). Damp housing was also a predisposing for recurrent exacerbation (odds ratio 3.8, 95% confidence interval 1.1-12.8). In the 2-4 age group, damp housing was significantly associated with hospital admissions. (Wever-Hess *et al.*, 2000)
- Kilpelainen's study of Finnish university students also demonstrated a positive association between home dampness and current asthma. The risk of current asthma in damp homes was highest among subjects with atopic heredity. (Kilpelainen *et al.*, 2001)
- The International Study of Asthma and Allergy in Childhood studied Austrian children to investigate the influence of indoor risk factors on wheezing in children 6-9 years old. The study found that dampness or mould at home was associated with a significantly increased risk of childhood wheezing in the last 12 months (odds ratio 1.43 with 95% confidence interval 1.24-1.65). (Zacharasiewicz *et al.*, 1999)
- Norback and colleagues studied the effect of building dampness in dwellings in Sweden on the occurrence of current asthma. Current asthma was more common among subjects living in damp dwellings (odds ratio 1.8 with 95% confidence interval 1.1-3.0), particularly with dampness in the floor construction (odds ratio 4.6 with 95% confidence interval 2.0-10.5). (Norback *et al.*, 1999)
- Norback also studied the relationships between current asthma symptoms (wheeze or attacks of breathlessness) and the indoor environment and dampness in hospitals. Current asthma symptoms were reported by 17%, and 8% had doctor's diagnosed asthma. Asthma symptoms were more common (adjusted odds ratio = 8.6; 95% confidence interval 1.3-56.7) in two buildings with signs of dampness-related degradation of di(ethylhexyl)-phthalate (DEHP) in polyvinyl chloride (PVC) floor material, detected as presence of 2-ethyl-1-hexanol (2-32 µg/m³) in indoor air. Asthma symptoms were related to higher

relative humidity in the upper concrete floor construction, and ammonia in the floor. (Norback *et al.*, 2000a.)

- Bornehag and colleagues conducted the Nordic interdisciplinary review of the scientific evidence on associations between exposure to “dampness” in buildings and health effects (NORDDAMP). They evaluated 61 journal articles chosen from a literature search of 590 relevant peer-reviewed articles. Their review concludes that “dampness” in buildings appears to increase the risk for health effects in the airways, such as cough, wheeze and asthma. The relative risks were in the range of odds ratio 1.4 – 2.2. They concluded further that the evidence for a causal association between “dampness” and health effects is strong, though the mechanisms are unknown. (Bornehag *et al.*, 2001)
- Nicolai, Illi and von Mutius studied risk factors for the persistence of asthma and respiratory symptoms from childhood into adolescence. They concluded that dampness at home is a significant risk factor for the persistence of bronchial hyperreactivity and respiratory symptoms in children with asthma. (Nicolai *et al.*, 1998)

iv) Airway Inflammation

- Clinical examinations including nasal lavage and peak expiratory flow measurements were undertaken on personnel who worked in a damp office building that had microbial growth in mineral fiber insulation and gypsum board. The study indicated that exposures in the damp office building were associated with an inflammatory nasal mucosal response. (Walinder *et al.*, 2001)
- Norback and colleagues, cited above with respect to dampness and asthma, also confirmed that dampness in dwellings is associated with signs of inflammation. The average forced expiratory flow in one second (FEV1) was lower and peak expiratory flow (PEF) variability was higher in subjects from dwellings with floor dampness. Blood eosinophil count was increased in damp dwellings. (Norback *et al.*, 1999)

2.3.1.3 *summary of selected evidence*

The evidence cited suggests an association between dampness in housing and various adverse respiratory health effects, including:

- **exacerbation of asthma**
- **increased incidence of wheezing and other respiratory symptoms**
- **increased incidence of upper respiratory infections**

- **inflammation of the airways**

Conditions of dampness appear to exacerbate respiratory conditions both directly (e.g. exacerbation of existing asthma) and indirectly (e.g. increased incidence of upper respiratory infections, which in turn can exacerbate existing asthma).

There is not a great deal of evidence that clarifies exactly which mechanisms are involved in producing these health effects.

Later sections will review evidence related to specific exposures that may accompany dampness (e.g. mould, bacterial and dust mites).

2.3.1.4 remedial action to avoid exposure

In general, the environmental remedies most often chosen to reduce dampness in buildings are:

- **Remediate moisture damage by remedying the cause and removing mould and mouldy materials**
- **Improve building drainage to eliminate water flow into basements**
- **Improve building envelopes to reduce air infiltration/exfiltration and water leakage**
- **Introduce sufficient local and general ventilation to keep rooms dry (e.g. bathroom)**
- **Introduce dehumidification to building areas subject to greater moisture (e.g. basements in humid summer months)**

2.3.2 Mould

2.3.2.1 nature of the contaminant and its sources

- Mould (a term used for microfungi) is most common in situations where conditions indoors are very moist, either from condensation of airborne water vapour on building surfaces (e.g. on or within uninsulated walls), or from leakage of water, whether by rain or runoff into the building or from pipes and taps inside the building. (Johanning, 1998)
- Mould spores are so small they cannot be seen except under a microscope, and they are very light and travel on air currents. Because mould spores are always present in outdoor air, they will migrate indoors and be deposited on building material surfaces. If the surfaces contain enough water, the spores will begin growing and will be seen when the colony has developed mycelia (the “cottony” growth characteristic of mould). The colony will produce more spores which in turn will spread and colonize a larger surface area. (Bartlett, 2001)
- Dampness in buildings usually gives rise to the growth of a number of different species of moulds simultaneously, and in fact, exclusive exposure to any one mould, particularly the more toxic varieties, is rare. (Johanning, 1998) In addition,

different building materials acquire a different repertoire of mould species in the presence of moisture.

- The following table lists the top 12 species of microfungi isolated from North American wallboard. Fifty percent of the top 12 species isolated are toxin producing. (Miller, 1998)

Fungus	% of 2134 wallboard samples
<i>Chaetomium globosum</i>	47.6
<i>Penicillium viridicatum</i>	38.1
<i>Eurotium herbariorum</i>	33.0
<i>Penicillium aurantiogriseum</i>	26.4
<i>Penicillium citrinum</i>	26.1
<i>Stachybotrys chartarum</i>	21.5
<i>Aspergillus sydowii</i>	10.7
<i>Penicillium chrysogenum</i>	7.6
<i>Penicillium commune</i>	7.3
<i>Eurotium repens</i>	5.8
<i>Memnoniella echinata</i>	4.1
<i>Aspergillus versicolor</i>	3.9

- Different mould species have different requirements for the amount of water necessary to grow. The species listed above cover a range of possible water contents of colonized material. Some species require very little moisture to grow; others require that the building material be virtually water-saturated.
- Studies at the Institute of Hygiene in Belgium revealed that the sites more often contaminated in the home are: (Summerbell *et al.*, 1992)
 - kitchen and bath rooms (*Cladosporium cladosporioides*, *Cladosporium sphaerospermum*, *Ulocladium botrytis*, *Chaetomium globosum*, *Aspergillus fumigatus*)
 - wallpaper (*C. sphaerospermum*, *Chaetomium species*, *Doratomyces species*, *Fusarium species*, *Stachybotrys atra*, *Trichoderma species*, *Scopulariopsis species*)
 - mattresses, carpets (*Penicillium species*, *Aspergillus versicolor*, *Aureobasidium pullans*, *Aspergillus repens*, *Wallemia sebi*, *Chaetomium species*)
 - window-frames (*A. pullulans*, *C. sphaerospermum*, *Ulocladium species*)
 - cellars and crawl spaces (*A. versicolor*, *A. fumigatus*, *Fusarium species*)
 - the soil of ornamental plants (*A. fumigatus*, *Aspergillus niger*, *Aspergillus flavus*)
 - insulation material (*A. versicolor*, *A. fumigatus*, *Fusarium species*).
- A Belgian study of 130 homes over a 10-year period ranked mould growth by species in indoor environments. The ten most common species were *Cladosporium*, *Penicillium*, *Aspergillus*, *Aureobasidium*, *Scopulariopsis*, *Alternaria*, *Acremonium*, *Ulocladium*, *Mucor*, and *Rhizopus* species. (Beguin & Nolard, 1994)
- In a Danish study of 72 mould-contaminated building materials from 23 buildings suffering from water damage, the microfungus genera most frequently encountered

were *Penicillium* (68%), *Aspergillus* (56%), *Chaetomium* (22%), *Ulocladium* (21%), *Stachybotrys* (19%) and *Cladosporium* (15%). *Penicillium chrysogenum*, *Aspergillus versicolor*, and *Stachybotrys chartarum* were the most frequently occurring species. (Gravesen *et al.*, 1999)

- One species that has received considerable attention is *Stachybotrys Chartarum*. *Stachybotrys chartarum* is a type of mould that can potentially produce potent mycotoxins. It has been implicated recently in episodes of human illness in both housing and portable school classrooms. In a study listing moulds most frequently isolated from the air of 47 dwellings in Central Scotland, *Stachbotrys* was found in 12.8% of dwellings, and ranked 16th among the top 19 species. (Hunter *et al.*, 1988)
- Specific identifiable components within certain moulds can adversely affect human respiratory health. For example, the compound (1→3)-β-d-glucan is a major structural component of almost all fungal cell walls. (Summerbell, 1998) A study in Erfurt and Hamburg, Germany, demonstrated the following associations between significant increases in (1→3)-β-d-glucan levels and the following housing characteristics:
 - Carpets in the living room (means ratio (MR) 1.9-2.1)
 - Keeping a dog inside (MR 1.4)
 - Use of the home by four or more persons (MR 1.4)
 - Lower frequency of vacuum cleaning (MR 1.6-3.0)
 - Lower frequency of dust cleaning (MR 1.4)
 - Presence of mold spots during the past 12 months (MR 1.4).

The researchers also found that the (1→3)-β-d-glucan concentrations in house dust, measured in µg/m², are also correlated with levels of endotoxins, allergens and culturable mold spore counts in house dust. (Gehring *et al.*, 2001)

2.3.2.2 selected evidence suggesting adverse respiratory effects

i) Asthma

- In Kilpelainen's study of Finnish university students cited earlier, the strongest association discovered was between exposure to visible mould and asthma. (Kilpelainen *et al.*, 2001)
- Norback and colleagues, in the study on building dampness cited earlier, also showed that immediate type allergy to moulds (*Cladosporium* and *Alternaria*) was more prevalent in damp dwellings (9.3% incidence vs. 3.9%). Further, they demonstrated that the mould allergy was associated with current asthma (odds ratio 3.4, confidence interval 1.4-8.5). (Norback *et al.*, 1999)

- A study by Taskinen and colleagues in eastern Finland compared schools with moisture and mould problems to a reference school. Their results demonstrated an association between the presence of moulds, atopic allergy to these moulds, and asthma or asthma-like conditions. All the children with skin prick test reactions to moulds reacted to at least one of the moulds used to indicate dampness (*Fusarium roseum*, *Aspergillus fumigatus*, *Phoma herbarum* or *Rhodotorula rubra*). The presence of these moulds was a criterion for choosing problem buildings. All the reactive children had either asthma or wheezing. (Taskinen *et al.*, 1997)

ii) Respiratory Symptoms

- In a Canadian study of some 14,799 adults at least 21 years of age, questionnaires were administered to investigate the association between home dampness and mold and health. The presence of home dampness and/or molds was reported by 38% of respondents. The prevalence of lower respiratory symptoms (any cough, phlegm, wheeze, or wheeze with dyspnea) was increased among those reporting dampness or mould compared with those not reporting dampness or mould. The authors concluded that exposure to home dampness and mould is a risk factor for respiratory disease in the Canadian population. (Dales *et al.*, 1991a)
- A review of nine population-based studies indicated one or more positive associations between mould levels and health outcomes as measured by symptoms of respiratory disease in seven of the nine cross-sectional studies identified. The studies also indicated that dampness and mold problems are present in 20% to 50% of modern homes. The authors concluded that moulds do contribute to allergic disease, and the extent of their involvement is probably greater than is indicated by the available clinical and epidemiologic studies. (Verhoeff & Burge, 1997)
- In a study of Finnish flats and terraced houses, occupants were compared for respiratory symptoms between homes with visible mould growth and those without a mould problem. The occurrence of respiratory symptoms (including rhinitis, sore throat, hoarseness, cough, phlegm, tight chest, dyspnea, and wheezing) was significantly higher in the exposed group than in the non-exposed. Cough and dyspnea were relieved in most cases during interruption of exposure (e.g. on vacations). Symptoms of chronic bronchitis were significantly more common in the exposed group (odds ratio 3.4, 95% confidence interval

1.1-10.9), when adjusted for age, sex, atopy and smoking. (Husman *et al.*, 1993)

- In a more recent study, exposure to mould was significantly associated with cough without phlegm, nocturnal cough, sore throat, rhinitis, fatigue and difficulties in concentration. While this type of association between respiratory infections and exposure to moisture or mould has previously been reported for children, the finding for adults is new. (Koskinen *et al.*, 1999)
- In an attempt to generate more definitive data on health effects of mouldy buildings, one research group undertook nasal lavage fluid analysis to determine whether inflammatory markers showed changes in persons exposed to mouldy buildings. Their results comparing a mould-exposed and a reference group indicated an association between inflammatory markers in the nasal lavage fluid, the high prevalence of respiratory symptoms among the occupants (such as cough, phlegm production and rhinitis), and chronic exposure to moulds in the indoor environment. (Hirvonen *et al.*, 1999).
- Dales *et al.* attempted to confirm by objective measures whether the associations that have hitherto been detected using questionnaires were supportable by measurement. Quantitative and qualitative mould measures (airborne ergosterol and viable microfungi in dust) were compared to respiratory symptoms and nocturnal cough recordings in Canadian elementary school children during the winter of 1993-1994. There was a 25-50 percent relative increase in symptom prevalence when mould was reported to be present ($p < 0.05$). But neither symptoms nor recorded cough was related to objective measures of mould. The researchers conclude that either these objective measures or the traditionally used questionnaire data are inaccurate, and that this discrepancy limits the acceptance of a causal relation between indoor microfungus growth and illness. (Dales *et al.*, 1999)
- Douwes and colleagues evaluated the use of extracellular polysaccharides of *Aspergillus* and *Penicillium* mould species (EPS-Asp/Pen) in house dust as a marker for mould exposure, and in turn studied the relation between EPS-Asp/Pen levels and home dampness and respiratory symptoms in children. They found that EPS-Asp/Pen levels in living room floor dust were positively associated with occupant-reported home dampness, and with respiratory symptoms. (Douwes *et al.*, 1999)

- Airborne (1→3)-β-d-glucan was measured in buildings in which complaints of eye and airway irritation as well as fatigue and skin symptoms had been numerous. The presence of symptoms was evaluated using questionnaires. Dose-response relationships were found between levels of (1→3)-β-d-glucan and eye and throat irritation, dry cough and itching skin. (Rylander *et al.*, 1992)

iii) Common Cold and Other Respiratory Infections

- The study of Finnish flats and houses by Husman *et al.* also found that the percentage of adults who had at least one acute respiratory infection during the previous 12 months was significantly higher in the mould-exposed group than in the non-exposed. The risk of acute respiratory infections associated with the exposure was 2.2 (95% confidence interval 1.2-4.4) when adjusted for age, sex, smoking and atopy. Schoolchildren in problem dwellings had recurrent respiratory infections requiring antibiotic treatment (e.g. tonsillitis, sinusitis, and acute bronchitis) more often than their non-exposed references. The occurrence of all respiratory infections in children under seven years was significantly higher in the study group than in the reference group. (Husman *et al.*, 1993)
- Kilpelainen's study of Finnish university students cited earlier also found an association between exposure to visible mould and common colds. (Kilpelainen *et al.*, 2001) Koskinen *et al.* also reported a significant association between exposure to mould and the common cold. (Koskinen *et al.*, 1999)

iv) Airway Inflammation

- In an animal study, acute inflammatory response in the lungs was studied in guinea pigs after a single inhalation exposure of (1→3)-β-d-glucan. In the water insoluble form, (1→3)-β-d-glucan caused a delayed response in terms of a decrease in macrophages and lymphocytes in the lung wall, 1 to 7 days after exposure. (Fogelmark *et al.*, 1992).
- A later paper reviewed field studies in which (1→3)-β-d-glucan was measured as a marker of biomass and was related to the extent of symptoms and measures of inflammation among exposed subjects. Increased levels of (1→3)-β-d-glucan were related to an increased extent of symptoms and markers of inflammation. The data suggest that

(1→3)-β-d-glucan can be used as a risk marker in indoor environments.” (Rylander, 1999 and 2000)

- Laboratory studies are also supportive of an association between (1→3)-β-d-glucan and activation of pulmonary alveolar macrophages (PAMs), possibly making the lungs hyperreactive to a wide variety of foreign materials. (Summerbell, 1998) Fungal glucan decreases phagocytosis and decreases pulmonary alveolar macrophage numbers (Miller and Day, 1997) Also, in double-blind inhalation exposure trials conducted with human volunteers, exposure to (1→3)-β-d-glucan correlated significantly with some non-specific respiratory symptoms. The most strongly correlating symptom was headache. (Summerbell, 1998)
- Pulmonary alveolar macrophage function and the immune system response to (1→3)-β-d-glucan are only partially understood. It appears that exposure causes inflammatory changes in lymphocytes, decreases lymphocyte mitogenicity and interleukin-1 (IL-1) secretion (via T-cells) and stimulates bacterial and tumor defences. (Miller and Day, 1997)

v) Lung Function

- Peak expiratory flow (PEF) variability was investigated in 148 children 7 to 11 years of age, of whom 50% had self- or parent-reported chronic respiratory symptoms. Endotoxin and (1→3)-β-d-glucan were measured in dust extracts. The levels of (1→3)-β-d-glucan per square meter of living room floor were significantly associated with peak flow variability, particularly in atopic children with asthma symptoms. No associations were found with endotoxin levels, or for levels of either microbial agent and bedroom floor or mattress dust. (Douwes *et al.*, 2000)

vi) Ideopathic Pulmonary Haemorrhage and Pulmonary Hemosiderosis

- At very high exposure levels to specific moulds, nose bleeding, hemoptysis, and pulmonary haemorrhage have been documented. (Rylander & Etzel, 1999)
- A geographic cluster of 10 cases of pulmonary haemorrhage and hemosiderosis in infants occurred in Cleveland, Ohio, between January 1993 and December 1994. An early study into the cases observed a greater frequency of water damage in homes of affected infants compared to those of controls. (Montaña *et al.*, 1997) The finding of water damage led to air and surface sampling for mold, which revealed

heavier growth of several fungi in case homes. The toxigenic fungus *Stachybotrys chartarum* was found in almost all of the case homes studied and about half of the control homes. (Dearborn, 1997) However, the causal connection between *Stachybotrys chartarum* exposure and respiratory illness has not been well established, because it has not been studied in the absence of other mould exposures.

- A community-based control study was undertaken to test the hypothesis that the 10 infants were more likely to live in homes where *Stachybotrys chartarum* was present than were 30 age-matched and ZIP code-matched control infants. (Etzel *et al.*, 1998) The infants' home environments were investigated using biosampling methods with specific attention to *Stachybotrys chartarum*, and air and surface samples were collected from the room where the infant was reported to have spent the most time.
- Viable *Stachybotrys* spores were detected in filter cassette samples of the air in homes of 5 of 9 patients, and 4 of 27 controls. The mean concentration of *Stachybotrys chartarum* was 43 CFU/m³ in homes of patients vs. 4 CFU/m³ in homes of controls when averaged across all media. The mean concentration of *Stachybotrys chartarum* on surfaces was 20×10^6 CFU/g and 0.007×10^6 CFU/g in homes of patients and controls, respectively. Other fungi such as *Aspergillus*, *Cladosporium*, and *Penicillium* were also identified, with mean CFU counts for all fungi averaging 29,227 CFU/m³ in homes of patients vs. 707 CFU/m³ in those of controls. The researchers concluded:

“Infants with pulmonary haemorrhage and hemosiderosis were more likely than controls to live in homes with toxigenic *Stachybotrys [chartarum]* and other fungi in the indoor air.” (Etzel *et al.*, 1998).
- Between 1993 and 1998, a total of 37 cases of pulmonary haemorrhage and hemosiderosis were identified in the Cleveland vicinity, including the initial cluster of ten cases. Twelve of the infants have died, including seven who were originally identified as sudden infant death syndrome. Thirty of these cases were African American children who lived within a contiguous nine zip code area in the eastern part of the metropolitan area. This residential area contains primarily wood frame homes, most of which were more than 60 years old. The area is a drainage plain where basements are frequently flooded in heavy rainstorms. The forced air heating in these homes commonly draws air

from the entire basement, providing a means for airborne particulates to be circulated up into the infants' sleeping areas. (Dearborn *et al.*, 1999)

- Researchers at the Texas Children's Hospital treated a seven-year old boy who had been asymptomatic until his family moved into a 25-year old farmhouse that had suffered from severe flood damage and was being reconstructed in stages. Bronchoalveolar lavage (BAL) fluid showed a moderate number of hemosiderin-laden macrophages (26%), indicating intrapulmonary bleeding, and grew *Stachybotrys chartarum* in Sabouraud-dextrose agar medium. Multiple cultures in the home grew *Stachybotrys chartarum*, and *Aspergillus* and *Penicillium* species were also recovered. The researchers concluded:

“In summary, we report the first isolation of *Stachybotrys atra* from the BAL fluid of a child with PH [pulmonary hemosiderosis]. The isolation of the organism from the patient's water-damaged home and the resolution of symptoms after his move to another home provide additional evidence that environmental exposure to *Stachybotrys atra* was responsible for the patient's pulmonary disease. Although the focus has previously been on *Stachybotrys atra* and infants with PH, our case demonstrates that *Stachybotrys atra* is also associated with PH in older children.” (Elidemir *et al.*, 1999)

While the physical evidence in the water-damaged home indicates that *Stachybotrys* was present in conjunction with other molds, the case study reports only the culture of *Stachybotrys* in the BAL fluid. The published documentation was not sufficient to determine whether other species had also been cultured in the BAL fluid. The authors do indicate that they failed to find sources of contamination from the equipment used during and after the bronchoscopy, suggesting that growth of *Stachybotrys* in the BAL fluid did indeed represent actual recovery of *Stachybotrys* spores from the patient.

- A review within the Center for Disease Control (CDC) and by outside experts of an investigation of acute pulmonary haemorrhage/hemosiderosis in infants identified shortcomings in the implementation and reporting of the investigation. The reviews led CDC to conclude that a possible association between acute pulmonary haemorrhage and hemosiderosis in infants and exposure to molds, specifically *Stachybotrys chartarum*, was not proven. (CDC, 2000)

2.3.2.3 *summary of selected evidence*

The evidence cited suggests an association between mould exposure in housing and various adverse respiratory health effects, including:

- **exacerbation of asthma**
- **development of allergy to mould**
- **increased incidence of wheezing and other respiratory symptoms**
- **increased incidence of upper respiratory infections**
- **inflammation of the airways**
- **changes in lung function, e.g. increased peak flow variability**
- **idiopathic pulmonary haemorrhage**

Mould appears to exacerbate respiratory conditions both directly (e.g. exacerbation of existing asthma) and indirectly (e.g. increased incidence of colds and increased sensitization).

To evaluate the health consequences for children of indoor exposure to moulds, an international workshop was organized with 15 scientists from 8 countries in Alexandria, Virginia, April 21-24, 1998. The participants agreed that exposure to moulds constitutes a health threat to children resulting in respiratory symptoms in both the upper and lower airways, an increased incidence of infections, and skin symptoms. Allergy, either to moulds or to other indoor agents, also presents a health risk. (Rylander & Etzel, 1999).

With respect to exposures to specific toxic moulds, the consensus is more cautious about specific conclusions. For example, in the wake of the Cleveland cases, the American Academy of Pediatrics published guidelines in 1998 for pediatricians concerning toxic mold exposures in children. It is interesting that their approach invokes the “precautionary principle”:

“Very little is currently known about acute idiopathic pulmonary haemorrhage among infants. This is a newly recognized problem and knowledge is expected to be evolving rapidly. In view of the severity of the problem, environmental controls to eliminate water problems and to reduce the growth of indoor molds are wise. Until more is known about the etiology of idiopathic pulmonary haemorrhage, prudence dictates that pediatricians try to ensure that infants under 1 year of age are not exposed to chronically moldy, water-damaged environments.” (American Academy of Pediatrics, 1998)

The study of a seven-year old boy with pulmonary hemosiderosis (PH) cited earlier led researchers to recommend that the American Academy of Pediatrics recommendations on mold exposure should include all children with PH, not just infants. (Elidemir *et al.*, 1999)

2.3.2.4 remedial action to avoid exposure

In terms of practical response and recommendations for physical changes to reduce illness, some agencies have recommended remediation to remove moulds. For example, a special Toxic Fungi Abatement Workshop was held at Case Western Reserve University in Cleveland, Ohio in March, 1996, to initiate a program to prevent pulmonary hemosiderosis in infants. The working group of scientists and public officials at the Workshop concluded that pulmonary hemosiderosis detected in infants in a specific locality in Cleveland was most likely explained by high exposure to mycotoxins in the spores, mycelia and substrate dusts from *Stachybotrys chartarum*. Given this conclusion, the working group refined a prevention program designed to detect homes of infants that might be at high risk, and to test these homes for *Stachybotrys chartarum* to ascertain the safety of the infant remaining in the home and to guide the extent of abatement necessary. (Cuyahoga County Board of Health *et al.*, 1996) As discussed above, the Center for Disease Control no longer concludes that there is any proven relationship between *Stachybotrys chartarum* and pulmonary haemorrhage and hemosiderosis. (CDC, 2000)

In addition, the New York City Department of Health promulgated guidelines on assessment and remediation of *Stachybotrys chartarum* in indoor environments. They emphasize that prompt removal of contaminated material and infrastructural repair must be the primary response to *Stachybotrys chartarum* contamination in buildings. They state that contamination should be prevented by proper building maintenance and prompt repair of water damaged areas. (New York City Department of Health, 1996) Since then, a new and broader New York protocol inclusive of all fungi has been issued, entitled "Guidelines on Assessment and Remediation of Fungi in Indoor Environments". (New York City Department of Health, 2000)

In general, the environmental remedies most often chosen to reduce health effects from microbiological contaminants are:

- **Remediate moisture damage by remedying the cause and removing mould and mouldy materials**
- **Eliminate standing water in ventilation or humidification systems**
- **Improve building drainage to eliminate water flow into basements**
- **Improve building envelopes to reduce air infiltration/exfiltration and water leakage**
- **Introduce sufficient local and general ventilation to keep rooms dry (e.g. bathroom)**

Canada Mortgage and Housing Corporation (CMHC) undertook a limited pilot study to assess the degree of improvement that might be available to asthmatic homeowners who undertook renovations to eliminate sources of indoor pollutants or mould. Five households with at least one asthmatic family member in each

joined the remediation study. Improvements in the asthma condition of the occupants correlated with the degree of improvement of the air quality of the house after remediation (e.g. reduction in mould detected in basements). Of the five homes, the adult asthmatic of House 1 did not find any improvement; the asthma of the owner of House 2 became worse while he gutted his basement; both daughter and mother in House 3 experienced significant improvement of asthma and chronic fatigue symptoms, respectively, after the renovation; and the adult asthmatics of Houses 4 and 5 reported marked improvement and no longer needed medication half a year to nine months after the renovation. (Canada Mortgage and Housing Corp., 1999)

2.3.3 Bacteria

2.3.3.1 *nature of the contaminant and its sources*

- Bacteria can be found indoors in situations where there is warm standing water, e.g. in humidifier trays or in the condensate from air conditioning coils. (Riley, 1982) Bacteria can affect human health indoors by infection, exposure to antigens, or exposure to toxins.
- *Legionella* is an example of an infectious bacteria that is found in ground water but that can multiply in air conditioning systems, humidifiers, whirlpools, grocery store mist machines, respiratory therapy devices, showers, excavation sites, industrial lubricants, hot tubs, and hospital water. (Ayars, 1997) For disease to occur, there has to be a way of aerosolizing water from a source containing the *Legionella*, a pathway for the aerosol to reach susceptible individuals, and then inhalation of the aerosol by those individuals (e.g. taking a shower supplied by a *Legionella*-contaminated water system). Infections may occur sporadically, occur as part of an outbreak, or be acquired during a hospitalization. (Barry, 2001)
- Actinomycetes are a group of rod-shaped, filamentous, fungus-like bacteria (mostly anaerobic) that can affect people who become sensitized to their antigen. (Access Excellence, 2001) (Ayars, 1997) Thermophilic actinomycetes have been isolated from soil, grain, compost and hay, and can contaminate forced air heating and cooling systems in buildings. (Ayars, 1997) The *Streptomyces* strain of Actinomycetes are mesophilic gram-positive bacteria which can be detected commonly in indoor air of houses with mould problems. (Hirvonen *et al.*, 1997a and 1997b)
- Bacterial endotoxins are pro-inflammatory substances that are present in the outer membrane of Gram-negative bacteria, and that are shed from the membrane during

growth or death of the bacteria. Endotoxins are ubiquitous outdoors, and are present in various industrial settings, particularly agricultural industries where organic dust is present. In the non-industrial indoor setting, endotoxins have been detected in settled dust and bioaerosols. Contaminated humidifiers can cause high background levels of airborne endotoxin in homes and offices. (Myatt and Milton, 2001)

- In a study of the homes of 86 infants with wheeze in Denver, USA, Greda *et al.* found that higher house dust endotoxin levels were associated with the presence of animals in the home. Lower house dust endotoxin levels were associated with central air conditioning, especially during months of typical use. (Greda *et al.*, 2001)

2.3.3.2 *selected evidence suggesting adverse respiratory effects*

i) Legionnaire's Disease

- *Legionella* species were first recognized as pathogens during a Legionnaire's convention outbreak in Philadelphia in 1976, in which 29 out of 184 people affected died. Typical symptoms of Legionnaire's Disease include malaise, myalgias, and headache early on, followed by dry cough, chest pain, diarrhea, abdominal pain and altered mental status. *Legionella* organisms may also be implicated in a flu-like illness without pneumonia known as Pontiac Fever. (Ayars, 1997)
- Reports of *Legionella* contamination have been in the non-residential setting. In theory similar conditions that allow growth of this bacteria could present in the residential setting, but in practice, this, to this author's knowledge, has not been reported.

ii) Hypersensitivity Pneumonia (Allergic Alveolitis)

- Hypersensitivity pneumonitis or extrinsic allergic alveolitis is an immunological respiratory syndrome that results from the inhalation of and sensitization to organic dust which can be bacterial, fungal or antigenic in nature, including bacteria such as Actinomycetes, other organisms such as the amoeba *Naegleria* and *Acanthamoeba*, and proteins from animal sources (e.g. rat urine). (Ayars, 1977) While many of the forms of extrinsic allergic alveolitis are due to specific occupational exposures (see Appendix 1 for details), endotoxins that can be found in standing water (e.g. in household humidifiers) can also be responsible.

iii) Organic Dust Toxic Syndrome

- In Organic Dust Toxic Syndrome (ODTS), symptoms begin 4-8 hr. after a single heavy organic dust exposure and include malaise, myalgias, dyspnea, cough, headache and nausea. It differs from hypersensitivity pneumonitis in that no prior sensitization is required, chest radiographs are generally normal, and no chronic sequelae occur.
- Bacterial endotoxin, fungi, molds and animal products including excreta have been labelled as likely contributors to ODTS. Exposures leading to ODTS are unlikely in housing except during renovation of badly moisture-damaged buildings.

iv) Airway Inflammation

- Recent study has demonstrated that spores of *Streptomyces* sp. are capable of stimulating certain macrophages to produce nitric oxide, pro-inflammatory cytokines, tumor necrosis factor and interleukin-6. The ability of *Streptomyces* sp. spores to induce expression of inducible NO synthase (iNOS) in macrophage cell lines is of particular interest because nitric oxide (NO) is known to be produced in the airways by both epithelial cells and inflammatory cells such as macrophages, and iNOS is not detectable in healthy tissue or cells. Moreover, marked increase in the concentration of exhaled NO has been recently described in asthmatic patients. This new data suggests a mechanism by which *Streptomyces* sp. may lead to respiratory tract disorders in individuals who live in mouldy houses. (Hirvonen *et al.*, 1997a and 1997b) (Huttunen *et al.*, 2000)
- Further study of the same bacteria revealed that the ability of the bacteria to induce production of important inflammatory mediators and to evoke cytotoxicity in macrophages is influenced as well by the growth conditions under which the bacteria is cultured, in this case by different brands of plasterboards, which differ in their detailed core composition and material content. (Murtoniemi *et al.*, 2001).
- Bacterial endotoxins are known to cause an inflammatory response in the human respiratory tract. The response is mediated by the proinflammatory cytokines IL-1, IL-6, IL-8 and TNF-alpha, and gives rise to general symptoms (fever, headache, malaise), respiratory symptoms (tightness of chest, dry cough) and lung function decrements. (Danuser and Monn, 1999).

v) Asthma

- Bacterial endotoxins have been shown to enhance the inflammatory response to inhaled allergens, and endotoxin exposure has been considered as one possible factor in an increase in asthma worldwide. (Platts-Mills *et al.*, 1997) Reed and Milton have hypothesized that airborne endotoxin adversely affects patients with asthma by increasing the severity of the airway inflammation; and by increasing the susceptibility to rhinovirus-induced colds. (Reed and Milton, 2001)
- At the same time as endotoxin exposure has been gaining attention for its hypothesized potential to exacerbate allergy and asthma in individuals with established disease, it is also being studied for the potential of exposure early in life to limit the development of allergy. (Gereda *et al.*, 2001) Reed and Milton postulate that exposure to airborne endotoxin in infancy may protect against asthma by promoting enhanced T(H)1 response and tolerance to allergens. (Reed and Milton, 2001)

vi) Pulmonary tuberculosis

- Pulmonary tuberculosis is transmissible on indoor air (Riley, 1982), but it is not a common residential contaminant in Canada.

2.3.3.3 summary of selected evidence

The evidence cited suggests an association between bacterial or bacterial endotoxin exposure in housing and various adverse respiratory health effects, including:

- **exacerbation of asthma**
- **increased incidence of respiratory symptoms, including cough and dyspnea**
- **increased incidence of upper respiratory infections**
- **chronic bronchitis and emphysema**
- **inflammation of the airways**
- **hypersensitivity pneumonia**

Bacterial endotoxin appears to exacerbate respiratory conditions both directly (e.g. exacerbation of existing asthma) and indirectly (e.g. increased incidence of colds, which in turn can exacerbate existing asthma). Chronic exposure can lead to serious respiratory effects including bronchitis and emphysema.

There is also evidence that airborne bacterial endotoxin in infancy may protect against asthma by promoting enhanced T(H)1 response and tolerance to allergens.

2.3.3.4 remedial action to avoid exposure

In general, the environmental remedies most often chosen to reduce health effects from bacterial contaminants are the same as for dampness in general, plus attention to standing water in humidifying and air conditioning systems:

- **Remediate moisture damage by remedying the cause and removing mould and mouldy materials**
- **Eliminate standing water in ventilation or humidification systems**
- **Improve building drainage to eliminate water flow into basements**
- **Improve building envelopes to reduce air infiltration/exfiltration and water leakage**
- **Introduce sufficient local and general ventilation to keep rooms dry (e.g. bathroom)**
- **Introduce dehumidification in higher moisture areas (e.g. basements in humid summer months)**
- **Avoid leaving biodegradable substrates in high moisture areas (e.g. cardboard boxes on basement floors)**

2.3.4 Viruses

2.3.4.1 nature of the contaminant and its sources

- Airborne viruses can be transmitted from person to person indoors, particularly where fresh air ventilation is inadequate. Infectious organisms can be atomized by coughing, sneezing, singing and even talking. Some of the droplets evaporate to droplet nuclei and disperse rapidly and randomly throughout the air of enclosed spaces. Since the droplet nuclei have negligible settling velocity they travel wherever the air goes. Measles and other childhood contagions, as well as the common respiratory virus infections (common colds) are transmissible on indoor air. (Riley, 1982)
- Respiratory viruses in the home transmit to uninfected people when an uninfected person makes contact with an infected person or with a virus-contaminated object. Influenza virus appears to be spread mainly by airborne droplet nuclei. The relative role of different means of transmission of rhinoviruses indoors is still controversial. (Goldmann, 2000)
- It has been assumed, but never proved, that ventilation rates sufficient to assure comfort for most room occupants would also control other airborne pollutants, including infectious agents. While there are examples of extensive airborne transmission under conditions of poor ventilation, substantial transmission also occurs where comfort criteria are satisfied. (Calder *et al.*, 1991) (Nardell *et al.*, 1991) (Nardell, 2001)

2.3.4.2 *selected evidence suggesting adverse respiratory effects*

i) Asthma

- Upper respiratory viral infections have been associated with 80-85% of asthma exacerbations in school-age children. Johnston *et al.* studied 108 children ages 9-11 and detected viruses in 80% of reported episodes of reduced peak expiratory flow, 80% of reported episodes of wheeze, and in 85% of reported episodes of upper respiratory symptoms, cough, wheeze and a fall in peak expiratory flow. During periods without exacerbation of asthma symptoms, only 12 percent of the children had detectable viral infections. The most commonly identified virus type was rhinovirus. (Johnston *et al.*, 1995) (Fisk, 2001)
- Tarlo and colleagues studied one hundred and nineteen adults and children with asthma in two Canadian cities over a one-year period. Of these, 36 pairs completed the case-control study. The study showed that symptomatic colds (as determined by self-reporting of symptoms of fever, sore throat or increase in nasal symptoms) were the most common trigger of asthma exacerbations in the winter and spring. (Tarlo *et al.*, 2000)
- Busse *et al.* found that experimental rhinovirus infections enhance airway responsiveness and the likelihood that a late allergic reaction will occur to an antigen challenge. They confirmed that rhinovirus infections promote mast cell release of histamine and the recruitment of eosinophils to the airways. They concluded that their data support the concept that rhinovirus infections act to promote allergic inflammation and by this mechanism increase both the likelihood of asthma occurring and the severity of wheezing. (Busse *et al.*, 1997)
- The relationship between viral exposure and respiratory allergy is complex. Some studies have indicated that the more a child suffers from viral infections, the more the risk of atopy increases. Other studies indicate that development of allergy is reduced if a child enters day nursery before 12 months, and consequently is exposed early in life to viruses. (Dubus *et al.*, 2001) In a case-control study Bodner *et al.* found that having measles up to the age of three was associated with a lower risk of doctor-diagnosed asthma later in life (odds ratio 0.2, 95% confidence interval 0.03 to 0.8). They also confirmed that having two or more siblings was similarly related to lower risk of doctor-diagnosed asthma (odds ratio 0.1, 95% confidence interval 0.03 –0.8). (Bodner *et*

al., 2000) Busse concludes that evidence from natural measles exposure and nonwheeze-inducing lower respiratory tract infections in young children implicate early childhood viral infections as protective against the development of atopy and airway allergic sensitivity, although in later life viral airway infections exacerbate asthma symptoms. (Busse, 2000)

ii) Measles and Interstitial Pneumonia

- In a 1974 measles outbreak at a suburban elementary school in upstate New York, USA, recirculation of viruses in the ventilation system was strongly implicated as a primary factor exacerbating the outbreak. The index case was a girl in second grade who produced 28 secondary cases in 14 different classrooms. (Riley *et al.*, 1978) Measles virus can cause respiratory complications such as interstitial pneumonia. (Ikeda *et al.*, 2000) (Arai *et al.*, 2001)

iii) Lung Function and Airway Inflammation

- Bardin *et al.* demonstrated in a study of 22 volunteers that significant reductions in PEF (peak expiratory flow) were associated with experimental rhinovirus infection in some but not all normal and asthmatic subjects. (Bardin *et al.*, 2000) Although rhinoviruses are known as the most common upper respiratory pathogen, inducing the majority of common colds worldwide, current evidence also supports the possibility that rhinoviruses infect the lower airways, inducing a local inflammatory response. (Papadopoulos and Johnston, 2000)

2.3.4.3 *summary of selected evidence*

The evidence cited suggests an association between viral exposure in housing and various adverse respiratory health effects, including:

- **development of specific childhood diseases, e.g. measles, along with respiratory complications such as interstitial pneumonia**
- **exacerbation of asthma, particularly by rhinoviruses**
- **increased likelihood of late allergic reaction to antigen challenge**
- **decreased lung function**
- **inflammation of the airways**

There is also some evidence that viral infection in infancy may protect against asthma later in life.

While poor ventilation has been blamed for the transmission of some viruses (e.g. measles), it is not yet clear whether improved ventilation plays a significant role in reducing exposure to those viruses which aggravate asthma.

2.3.4.4 remedial action to avoid exposure

Adequate fresh air ventilation can dilute airborne viral concentrations indoors in the presence of infected individuals. Intervention studies have also shown that improved standards of education and personal hygiene (particularly handwashing) have considerable impact in the control and prevention of infectious organisms. (Barker *et al.*, 2001)

2.3.5 Dust Mites

2.3.5.1 nature of the contaminant and its sources

- Dust mites (*Dermatophagoides pteronyssinus* and *Dermatophagoides farinae*) are commonly found in bedding and carpeting when relative humidity levels are around 60% or above. Dust mites feed on human skin flakes and are about 300 microns in size. Dust mite fecal particles contain large amounts of the most common type I dust mite allergens (Der p 1 and Der f 1). The fecal particles are about 10 microns in size and heavier than air. When airborne, they settle out in about five minutes. Lying down on a bed can release puffs of dust that contain dust mite fecal particles. Dust mites themselves also generate type II allergens from their body parts. (Chandra *et al.*, 1997)
- In a Canadian study of the homes of 120 asthma patients in Vancouver and Winnipeg, the mean levels of mite allergens in mattress and floor samples were relatively low in both cities for all seasons. Only a few home characteristics were found to be related to mite allergen levels, such as the type and the age of the home, the type of heating, the use of feather pillows, and the number of occupants in the homes. Mite allergen levels were significantly higher in Vancouver, where indoor relative humidity is higher than in Winnipeg, but there was no significant association between the levels of indoor relative humidity and the levels of mite allergens after adjusting for variations in city, season and individual home. (Chan-Yeung *et al.*, 1995)
- A recent study measured personal domestic exposure to house dust mite allergen during a range of activities in houses in Sydney, Australia. Inhaled particles containing mite allergen (Der p 1) were collected using a nasal air sampler which impacts particles greater than approximately 5 microns in diameter) on a protein-

binding membrane. The bound particles were detected with immunostaining with monoclonal antibodies specific for Der p 1. The results were more sensitive than previous methods. The highest personal mite allergen exposure was detected while raising dust or sitting on a bed. The concentration of mite allergen in floor and bed dust was 19.4 and 55.1 µg/g respectively. (Poulos *et al.*, 1999)

- Alvarez and colleagues investigated dust mite antigen concentrations in homes in two Spanish cities (Las Palmas and Pamplona) with different climates within a temperate region. They determined that exposure to dust mite allergen (Der p1, Der f1 and Der 2) was influenced by climatic conditions and by dampness in homes. Antigen levels were higher in homes in Las Palmas than in Pamplona, but damp homes in Pamplona had higher Der p1 levels, similar to those detected in homes in Las Palmas. (Alvarez *et al.*, 1997)
- In later research, Alvarez and colleagues studied 31 mild and recently diagnosed asthma patients sensitized to dust mite, and collected dust samples from their beds. Most patients were exposed to Der p 1 levels under 2 µg/g of dust. (Alvarez *et al.*, 2000)

2.3.5.2 selected evidence suggesting adverse respiratory effects

i) Asthma

- Home exposure to high levels of house dust mite allergen has been shown to aggravate airway reactivity and asthma. (Shapiro *et al.*, 1999) In a study of risk factors for the persistence of asthma and respiratory symptoms from childhood into adolescence, Nicolai, Illi and von Mutius reported that higher mite antigen levels in the bed were associated with bronchial hyperreactivity. (Nicolai *et al.*, 1998)
- Platts-Mills concludes that for dust mite allergens, there is a dose response relationship between domestic exposure and sensitization. Since dust mite allergen provocation can induce many of the features of asthma, the findings strongly suggest that there is a causal relationship between dust mite allergen exposure in the home and asthma. Platts-Mills feels that the likely scenario is that allergen exposure over the first few years of life induces sensitization, and that continuing exposure can maintain inflammation in the nose and lungs. (Platts-Mills, 2000)
- Norback and colleagues demonstrated that building dampness is associated with an increase in current asthma and biochemical signs of inflammation. Their investigations did not find any relation, however,

between immediate type allergy to house dust mites and current asthma or building dampness. (Norback *et al.*, 1999)

- In the research by Alvarez and colleagues of 31 asthmatic subjects, discussed earlier, Der p 1 levels in bed dust samples were associated with asthma symptoms and sputum tryptase level, but not with bronchial hyperresponsiveness (BHR) or eosinophilic inflammation. They concluded that asthma symptoms and lung mast-cell activation are at least partially dependent on current allergen exposure. The researchers suggested that lack of correlation between mite exposure and eosinophilic inflammation and BHR supports the role of other factors that enhance the immunologic response initiated by the allergen, increasing the activity of asthma. (Alvarez *et al.*, 2000.)
- Tarlo and colleagues, in a Canadian case-control study cited earlier, showed that a transient increase in dust exposure can be a significant trigger of acute asthma exacerbation in persons with existing asthma. (Tarlo *et al.*, 2000)
- The timing of exposure and sensitization to allergens such as dust mites can affect the likelihood of developing wheezing later in life. In an examination of survey data concerning children enrolled in a Tucson, (Arizona) USA epidemiology study of obstructive airways disease, children sensitized to any allergen before eight years of age were compared to children sensitized after eight years of age. The children who were sensitized to any allergen before eight years were significantly more likely to report shortness of breath with wheeze (odds ratio 4.1), wheeze apart from colds (odds ratio 3.88) or wheeze most days (odds ratio 2.83). Children sensitized after eight years were no more likely to have the symptoms described above than children who were never found to be sensitized. The researchers concluded that early allergic sensitization is a significant risk factor for later development of wheezy symptoms, whereas late sensitization is not. (Sherrill *et al.*, 1999)

ii) Lung Function

- Most studies on bronchial allergen challenge concern patients with high levels of allergic sensitization. A recent study of bronchial reactions to dust mite in individuals with low skin reactivity to the allergen revealed that there can be airway changes in the absence of acute symptoms. Twenty subjects with low levels of allergic sensitization had an early decrease in the lung function parameter FEV1 (the average forced

expiratory flow in one second) of 8.6% ($p < 0.01$) and a mean late decrease of 6.3% ($p < 0.05$). There was also a trend for decrease in PC20 histamine twenty-four hours after allergen challenge. The decrease in lung function was unnoticed by most patients. (Witteman *et al.*, 1999)

2.3.5.3 summary of selected evidence

The evidence cited suggests an association between dust mite exposure in housing and various adverse respiratory health effects, including:

- **development of asthma**
- **exacerbation of asthma**
- **increased wheezing and other respiratory symptoms**
- **decreased lung function**

The Committee on the Assessment of Asthma and Indoor Air of the Institute of Medicine (U.S.) has concluded that there is sufficient evidence of a causal relationship between exposure to house dust mite allergen and the development of asthma in susceptible children. The committee also found sufficient evidence to conclude that there is a causal relationship between exposure to house dust mites and the exacerbation of asthma in sensitized individuals. (Institute of Medicine, 2000)

2.3.5.4 remedial action to avoid exposure

The Canadian Medical Association has concluded that the most common factors affecting asthma patients include allergens, respiratory irritants and viral infections. The Association advocates intense efforts to avoid relevant allergens and irritants. (Canadian Medical Association, 1999)

In general, the remedies most often chosen to reduce health effects from dust mites are:

- **Maintain indoor humidity at less than 60% R.H.**
- **Wrap items susceptible to mite growth in moisture-impermeable covers (e.g. mattresses)**
- **Maintain proper housekeeping to prevent build-up of dust deposits, including frequent dusting and vacuuming with an effective vacuum cleaner**
- **Reduction of clutter to allow easy cleaning**
- **Removal of carpets and drapes**

House dust mites can accumulate to very high levels in homes. A novel treatment of furnishings has been developed, based on the sensitivity of house dust mites to heat and of their allergens to steam. In a recent study, mattresses and duvets in homes of asthmatic subjects were treated with hot air (110 degrees C), followed by steam, and then by heat again. All their carpets were also steam cleaned. The study demonstrated that active heat-steam treatment of homes caused a sustained

reduction of house dust mite allergen, to below the risk level for sensitization, compared with no change in control homes. Patients whose homes were treated showed a four-fold reduction in bronchial hyperreactivity at nine months. These improvements were sustained for 12 months in a subset of patients whose homes were also retrofitted with bedroom ventilation units. (Htut *et al.*, 2001)

The Canadian Asthma Consensus Report of the Canadian Medical Association recommends a systematic program to eliminate, or at least substantially reduce, allergen exposure in sensitized people. It suggests that humidity in the home, including the bedroom, should be kept below 50%, and that additional measures should be taken to reduce dust mite exposure. In addition, exposure to environmental tobacco smoke and high concentrations of respiratory irritants should be avoided. It also cautions that reduction of exposure to pet allergens cannot be effective without removing the pet from the home. (Canadian Medical Association, 1999)

The Canadian Medical Association (CMA) concludes that there is insufficient information to recommend the use of residential air cleaners and humidifiers as an asthma remedy. (Canadian Medical Association, 1999) The American Thoracic Society does state more generally that persons seeking relief from problems related to indoor air quality, or attempting to minimize risk for developing problems can be counseled that using products that reduce exposure is reasonable. (American Thoracic Society, 1997) They note that it is doubtful that experimental data from controlled clinical trials will become available for low emission products or room and central air cleaners, and suggest that users need to be aware that purported health benefits may not follow.

The Committee on the Assessment of Asthma and Indoor Air of the Institute of Medicine (U.S.) cautions that it is difficult to draw general conclusions regarding the effectiveness of indoor environmental interventions. They note that for many allergens, effective remediation strategies consist of integrated approaches applied consistently over time. The two primary components of an integrated approach are removal or cleaning of allergen reservoirs, and control of new sources of exposure. Source removal, when it is possible, is typically the most effective control measure. (Institute of Medicine, 2000)

A double-blinded, randomized trial by Shapiro and colleagues demonstrated that aggressive dust mite intervention can decrease dust mite levels and improve (reduce) bronchial hyperresponsiveness. (Shapiro *et al.*, 1999)

2.3.6 Insects / Cockroaches

2.3.6.1 *nature of the contaminant and its sources*

- Cockroaches (*Blattella germanica*) are found indoors where there is food available. Cockroaches are particularly common to multi-unit dwellings where there may be passages between dwelling units which allow the insects to migrate from one unit to another.

2.3.6.2 *selected evidence suggesting adverse respiratory effects*

i) Asthma

- In one study of 222 children who were born to parents with asthma, allergies or both, cockroach allergen concentrations in the home were assessed. Compared to children with lower cockroach allergen exposure, children with higher exposures had higher relative risks for the development of asthma (doctor-diagnosed) and recurrent asthmatic wheezing. (Litonjua *et al.*, 2001).

ii) Lung Function

- In a Normative Aging Study of older adults, the cockroach allergen level in homes was determined to be a risk factor for accelerated decline of FEV1 (the average forced expiratory flow in one second). Levels of allergen Bla g 1 and Bla g 2 were significant predictors of decline in FEV1 after adjustment for age, smoking and baseline FEV1. The results were unchanged after elimination of asthmatic subjects from the analysis. (Weiss *et al.*, 1998)

iii) Respiratory Allergy

- Cockroach allergens constitute an important cause of environment-related respiratory allergy. (Liccardi *et al.*, 2000) Cockroach allergen sensitivity starts early in life and may be the only sensitizing allergen in many young inner-city children. In a study of 196 children in Chicago with recurrent wheezing, Alp *et al.* found that 23.8% of children under 4 years of age in their sample had cockroach allergen sensitivity, compared with only 12.7% who were skin test positive to dust mite allergen. (Alp *et al.*, 2001)

2.3.6.3 summary of selected evidence

The evidence cited suggests an association between cockroach antigen exposure in housing and various adverse respiratory health effects, including:

- **exacerbation of asthma**
- **decreased lung function**
- **respiratory allergy**

The Committee on the Assessment of Asthma and Indoor Air of the Institute of Medicine (U.S.) found sufficient evidence to conclude that there is a causal relationship between exposure to cockroaches and the exacerbation of asthma in sensitized individuals. (Institute of Medicine, 2000)

2.3.6.4 remedial action to avoid exposure

In general, the remedies most often chosen to reduce health effects from insect allergens are:

- **Maintain kitchen hygiene to avoid providing food sources to cockroaches**
- **Maintain proper housekeeping to prevent build-up of insect parts and household dust, including vacuuming with effective vacuum cleaner and frequent dusting**
- **Undertake programs to eliminate insect pests in the building, including integrated pest control methods.**

The Committee on the Assessment of Asthma and Indoor Air of the Institute of Medicine (U.S.) concluded that there is suggestive evidence that the combined use of cockroach extermination and control of potential reservoirs of allergen in beds, carpets, furnishings and clothing through cleaning can achieve a short-term decrease in cockroach allergen levels in indoor environments. Extermination alone appears ineffective because significant allergen levels remain in settled dust; cleaning alone in the absence of complete extermination does not eliminate the sources of the allergen. There has not been sufficient study to demonstrate whether cockroach mitigation or prevention strategies are associated with improved lung function, though the course of action would appear sensible. (Institute of Medicine, 2000)

2.3.7 Animal Dander

2.3.7.1 nature of the contaminant and its sources

- Pets, including cats, dogs, rabbits, hamsters, birds and other animals are all known for producing small particles, or dander, which include allergenic proteins (e.g. from cat saliva).

- The major cat allergen (*Felis domesticus*: Fel d 1) is carried by small-dimension particles (<5 microns in diameter) that readily become airborne and persist unmodified for a long time. Fel d 1 should be considered a ubiquitous antigen because it has been found in indoor environments and even in public places where a cat has never been kept. Recent research has demonstrated that clothing of cat owners may contribute to the dispersal of Fel d 1 in cat-free environments. (Liccardi, 2000)

2.3.7.2 *selected evidence suggesting adverse respiratory effects*

i) Asthma

- The International Study of Asthma and Allergy in Childhood (cited earlier) found that having a bird or a rabbit as a domestic pet was associated with a significantly increased risk of childhood wheezing in the last 12 months (for birds, odds ratio 1.40 with 95% confidence interval 1.06-1.85; for rabbits, odds ratio 1.37 with 95% confidence interval 1.03-1.82). (Zacharasiewicz *et al.*, 1999)
- A recent study in Sweden allowed the study of cat and dog allergen without confounding by the presence of dust mite allergen. In the northernmost region of Sweden, there is a 6-8% prevalence of asthma despite a very dry climate. The causes of an increase in asthma were not clear, but since conditions are unfavorable for dust mite growth, domestic animals were suspected to be the primary source of indoor allergens. Serum was collected from 110 asthmatic children, 55 children with symptoms of asthma but no established diagnosis, and 63 control children, all of 7-8 years in age. Serum IgE antibody assays on the 165 children with respiratory symptoms confirmed that there was a high degree of sensitization to cat, dog and birch allergen. Cat and dog allergens were present in almost all of the school dust samples taken as part of the study, and by contrast, dust mite and cockroach allergens were generally unmeasurable. (Perzanowski *et al.*, 1999)
- For some children, exposure to cat dander may bring a decreased risk of sensitization and asthma, since the dose-response relationship between cat exposure and sensitization is bell shaped (rather than linear as for dust mite exposure). Platts-Mills and colleagues showed that some children exposed to greater than 20 µg of Fel d 1 per gram of dust at home made an IgG and IgG4 antibody response to Fel d 1 without IgE antibody. This is a modified Th2 response not associated with

symptoms and is a form of immunological tolerance. (Platts-Mills *et al.*, 2001)

2.3.7.3 summary of selected evidence

The evidence cited suggests an association between animal dander exposure in housing and various adverse respiratory health effects, including:

- **exacerbation of asthma**
- **sensitization to the allergen**

The Committee on the Assessment of Asthma and Indoor Air of the Institute of Medicine (U.S.) found sufficient evidence to conclude that there is a causal relationship between exposure to cats and the exacerbation of asthma in sensitized individuals. They found an association between dog allergen exposures and exacerbation of asthma in individuals specifically sensitized to these allergens. They found suggestive evidence of an association between exposures to domestic birds and the exacerbation of asthma, although it was unclear what portion of this association is attributable to an allergic asthmatic response to the mites harboured by these birds. (Institute of Medicine, 2000)

2.3.7.4 remedial action to avoid exposure

In general, the remedies most often chosen to reduce health effects from animal dander are:

- **Remove pets from houses with pet-sensitive occupants**
- **Maintain pet-free zones for allergic individuals**
- **Proper housekeeping to prevent build-up of dust deposits, including vacuuming with effective vacuum cleaner and frequent dusting**
- **Removal of carpets and drapes**

Application of these remedies needs to be balanced with the knowledge that for some children, exposure to cat dander may bring a decreased risk of sensitization and asthma, since the sensitization curve is bell-shaped rather than linear.

There is suggestive evidence of an association between removal of a cat from the home and improvement of symptoms or lung function in cat-allergic asthmatics. Concomitant removal or isolation of known reservoirs of cat allergen (carpets, upholstery, mattresses, pillows) may be required to diminish allergen levels to those commonly measured in homes without cats. Suggestive evidence indicates that some measures short of removal (e.g. washing the animal) may result in transient reduction in allergen levels. However, there is insufficient evidence to determine whether or not an association exists between measures short of removal

of a cat from the home and improvement in symptoms in cat-allergic asthmatics. (Institute of Medicine, 2000)

Since cat allergen has been found in spaces not inhabited by cats, it has been concluded that the clothing of cat-owners may be responsible for dispersal of this allergen. Washing Fel d 1 contaminated clothing is a simple and effective method for removing this allergen from clothing and reducing the risk of cat allergen dispersal. (Liccardi, 2000)

2.3.8 Environmental Tobacco Smoke

2.3.8.1 *nature of the contaminant and its sources*

- Nonsmokers inhale “environmental tobacco smoke” (ETS), the combination of the sidestream smoke that is released from the cigarette’s burning end and the mainstream smoke exhaled by the active smoker. The inhalation of ETS is generally referred to as passive or involuntary smoking. The exposures of active and involuntary smoking differ quantitatively, and to some extent, qualitatively. Because of the lower temperature in the burning cone of the smoldering cigarette, most partial-pyrolysis products are enriched in the sidestream as compared to mainstream smoke. Consequently, sidestream smoke has higher concentrations of some toxic and carcinogenic substance than does mainstream smoke; however, dilution by room air markedly reduces the concentrations inhaled by the involuntary smoker in comparison to those inhaled by the active smoker. Nevertheless, involuntary smoking is accompanied by exposure to toxic agents generated by tobacco combustion. (Samet and Wang, 2001)

2.3.8.2 *selected evidence suggesting adverse respiratory effects*

i) Lung Cancer

- Cigarette smoking and other forms of tobacco smoking are the leading causes of lung cancer. The risk of lung cancer is increased by the presence of fibrotic lung diseases, and also varies by dietary factors and genetic history. (Samet and Cohen, 1999)
- In 1992 the U.S. Environmental Protection Agency published its risk assessment of ETS as a carcinogen. The agency’s evaluation drew on the toxicological evidence on ETS and the extensive literature on active

smoking. A metaanalysis of the studies published to that time was central in the decision to classify ETS as a known human carcinogen. The analysis also found a significantly increased risk of lung cancer in never-smoking women married to smoking men (odds ratio in U.S. studies 1.19, 90% confidence interval 1.04-1.35). Studies since that time have strengthened this conclusion, including one with 651 cases and 1253 controls in the United States that showed an increased relative risk (odds ratio 1.26, 95% confidence interval 1.04-1.54). (Samet and Wang, 2001)

- A more recent metaanalysis (Hackshaw *et al.*, 1997) included 37 published studies. The excess risk of lung cancer for smokers married to nonsmokers was estimated as 24 percent (odds ratio 1.24, 95% confidence interval 1.13-1.36). Adjustment for potential bias and confounding by diet did not alter the estimate. This metaanalysis supported the conclusion of the U.K. Scientific Committee on Tobacco and Health that ETS is a cause of lung cancer. (Scientific Committee on Tobacco and Health, HSMO 1998) (Samet and Wang, 2001)

i) Asthma

- Exposure to environmental tobacco smoke (ETS) has been shown to exacerbate the status of children with asthma and possibly to increase risk for asthma. It has also been shown to increase symptoms in adults with asthma. It is prudent to recommend elimination of ETS exposures in the home for children and adults with asthma. (American Thoracic Society, 1997)
- Samet and Wang conclude that neither epidemiologic nor experimental studies have established the role of ETS in exacerbating asthma in adults. The acute responses of adult asthmatics to ETS have been assessed by exposing persons with asthma to tobacco smoke in a chamber. This experimental approach cannot be readily controlled because of the impossibility of blinding subjects to exposure to ETS. However, suggestibility did not appear to underlie the physiological responses of asthmatics to ETS. Of three studies involving exposure of unselected asthmatics to ETS, only one showed a definite adverse effect. (Samet and Wang, 2001)
- Gilliland *et al.* investigated the effects of maternal smoking during pregnancy and childhood environmental tobacco smoke (ETS) exposure on asthma in a study of 5,762 school-aged children residing in 12 Southern California communities. In utero exposure to maternal

smoking without subsequent postnatal ETS exposure was associated with increased prevalence of:

- physician-diagnosed asthma (odds ratio 1.8, 95% confidence interval 1.1-2.9)
- asthma with current symptoms (odds ratio 2.3, 95% confidence interval 1.3-4.0)
- asthma requiring medication use in the previous 12 months (odds ratio 2.1, 95% confidence interval 1.2-3.6)

In contrast, current and previous ETS exposure was not associated with asthma prevalence. (See also Wheezing, below). (Gilliland *et al.*, 2001)

iii) Wheezing

- The International Study of Asthma and Allergy in Childhood (cited earlier) found that smoking of the mother during pregnancy and/or breastfeeding and smoking of the mother at the present time (exposing 6-9 yr. old children) were associated with a significantly increased risk of childhood wheezing in the last 12 months. For smoking during pregnancy/breastfeeding the odds ratio was 1.28 with 95% confidence interval 1.08-1.48; for present smoking the odds ratio was 1.25 with a 95% confidence interval 1.12-1.41. (Zacharasiewicz *et al.*, 1999)
- Gilliland's study of ETS exposure in Southern California, cited above, also showed an association between *in utero* exposure to maternal smoking without postnatal ETS exposure and the prevalence of wheezing as follows:
 - lifetime history of wheezing (odds ratio 1.8, 95% confidence interval 1.2-2.6)
 - current wheezing with colds (odds ratio 2.1, 95% confidence interval 1.3-3.4)
 - current wheezing without colds (odds ratio 2.5, 95% confidence interval 1.4-4.4)
 - persistent wheezing (odds ratio 3.1, 95% confidence interval 1.6-6.1)
 - wheezing with exercise (odds ratio 2.4, 95% confidence interval 1.3-4.3)
 - attacks of wheezing causing shortness of breath (odds ratio 2.4, 95% confidence interval 1.3-4.4) or awakening at night in the previous 12 months (odds ratio 3.2, 95% confidence interval 1.7-5.8)
 - wheezing requiring medication (odds ratio 2.1, 95% confidence interval 1.2-3.7) or emergency room visits during the previous year (odds ratio 3.4, 95% confidence interval 1.4-7.8)

Current and previous ETS exposure was consistently associated with subcategories of wheezing. Current ETS exposure was associated with:

- lifetime wheezing (odds ratio 1.3, 95% confidence interval 1.1-1.5)
- current wheezing with colds (odds ratio 1.6, 95% confidence interval 1.3-2.0)
- current wheezing without colds (odds ratio 1.5, 95% confidence interval 1.1-1.9)
- wheezing with exercise (odds ratio 1.7, 95% confidence interval 1.3-2.2)
- attacks of wheezing causing shortness of breath (odds ratio 1.6, 95% confidence interval 1.2-2.1) or awakening at night (odds ratio 1.5, 95% confidence interval 1.1-2.0)

- wheezing requiring medication (odds ratio 1.4, 95% confidence interval 1.1-1.8) or emergency room visits during the previous year (odds ratio 1.9, 95% confidence interval 1.2-3.0)

The effects of current ETS exposure on subcategories of wheezing were most pronounced among children exposed to two or more smokers, and remained significant when adjusted for maternal smoking during pregnancy. (Gilliland *et al.*, 2001)

iv) Other Respiratory Symptoms

- Several studies suggest that passive smoking can cause acute respiratory symptoms and illness in adults, but consistent evidence of an effect of passive smoking on chronic respiratory symptoms in adults has not been found. (Samet and Wang, 2001)
- Analysis of U.S. National Health Survey data showed that a pack-a-day smoker increases respiratory restricted days by about 20 percent for a nonsmoking spouse. (Ostro, 1989) A study of Los Angeles student nurses with a smoking roommate showed a significant increase in the risk of an episode of phlegm. In a Swiss study on air pollution and lung disease in adults, involuntary smoke exposure was associated with asthma, dyspnea, bronchitis and chronic bronchitis symptoms, and allergic rhinitis. A cohort study of 3914 nonsmoking participants in the Adventist Health Study showed an increased risk of new symptoms compatible with airway obstructive disease, with exposure to environmental tobacco smoke during both childhood and adulthood. Never-smoking Philadelphia residents with a reported diagnosis of asthma, chronic bronchitis or emphysema had sustained significantly greater exposure to tobacco smoke than unaffected controls. (Samet and Wang, 2001)

v) Lung Growth and Development

- During childhood, measures of lung function increase, more or less parallel to the increase in height. The 1986 U.S. Surgeon General's Report concluded on the basis of studies available at the time that involuntary smoking reduces the rate of lung function growth during childhood. Further studies since then have supported this conclusion. (Samet and Wang, 2001)

vi) Lower Respiratory Tract Illnesses in Childhood

- Investigations conducted throughout the world have demonstrated an increased risk of lower respiratory tract illness in infants with smoking parents. These studies indicate a significantly increased frequency of bronchitis and pneumonia during the first year of life of children with smoking parents. In a review of data from 39 studies, Strachan and Cook reported an approximately 50 percent increase in illness risk if either parent smoked; the odds ratio for maternal smoking was somewhat higher at 1.72 (with 95% confidence interval 1.55-1.91). (Strachan and Cook, 1997)

2.3.8.3 summary of selected evidence

The evidence cited suggests an association between tobacco smoke exposure in housing and various adverse respiratory health effects, including:

- **development of asthma through prenatal maternal smoking exposure**
- **exacerbation of asthma in children through current environmental tobacco smoke exposure**
- **increased respiratory symptoms in children and adults, including wheezing**
- **reduced rate of lung function growth in childhood**
- **increased frequency of lower respiratory tract illnesses in infants.**

The causal connection between active and passive smoking and the risk of development of lung cancer in adults has been extensively established in the literature.

2.3.8.4 remedial action to avoid exposure

Exposure to environmental tobacco smoke (ETS) has been shown to exacerbate the status of children with asthma and possibly to increase risk for asthma. It has also been shown to increase symptoms in adults with asthma. It is prudent to recommend elimination of ETS exposures in the home for children and adults with asthma. (American Thoracic Society, 1997)

Cessation of smoking is the ideal action to avoid family exposure to environmental tobacco smoke in their homes. If adults are unable or unwilling to quit, an alternative protection for family members is the creation of an internal or external smoking area that is totally excluded from the circulating air of the home. This solution is not perfect, since some smoke or odours of smoking residue may enter the home when the door is opened, and the smoker will carry combustion products back into the home on his or her clothing and breath. To avoid fetal exposure,

there is no viable alternative to cessation, although reduction is better than nothing.

2.3.9 Other Products of Combustion

2.3.9.1 *nature of the contaminant and its sources*

This category includes a number of gases and particles that arise from combustion of wood, gas, oil, kerosene, propane, candle wax or other fuel indoors. There are also some products of combustion, from furnaces, cars, trucks and industrial sources, that are present in outdoor air and which contribute to background levels of combustion products inside the home as well.

The role of combustion-related particulates in respiratory health will also be discussed in a later section.

i) Carbon Monoxide

- Carbon monoxide is a colourless, odourless gas that is produced by the incomplete combustion of any fuel containing carbon atoms. Carbon monoxide is very toxic, and can cause death.(Burr, 2001) It is usually encountered indoors at concentrations similar to outdoor levels (0.05 to 0.9 mg/m³ in rural areas (0.04 to 0.8 ppm) and 1.1 to 11 mg/m³ (1 to 10 ppm) in urban areas, with peaks in the latter up to 57 mg/m³ (50 ppm)). Higher concentrations can occur indoors when there is an open-flame appliance or a failure of a combustion appliance, either by leakage from exhaust pipes, or from backdrafting from a chimney. Backdrafting occurs when exhaust pressures from elsewhere in the house (e.g. clothes dryer or kitchen exhausts) exceed the chimney draft. Carbon monoxide levels of approximately 115 mg/m³ (100 ppm) have been found in the kitchens of some houses immediately after gas stoves were used for cooking. Health Canada's guidelines for acceptable short term exposure to carbon monoxide in residential indoor air are <11 ppm eight hour average concentration, and <25 ppm one-hour average concentration. (Health Canada, 1989)

ii) Nitrogen Dioxide

- Nitrogen dioxide (NO₂) is the only oxide of nitrogen that has been shown to be detrimental to human health at concentrations that may be encountered in indoor air. NO₂ may arise either from inadvertent

combustion leakage, or from unvented open flame appliances such as gas stoves. The indoor/outdoor ratio of nitrogen dioxide concentrations is generally less than unity in dwellings in which there are no major indoor sources, and greater than unity in dwellings with gas stoves or other unvented combustion appliances. Families who use gas for cooking are exposed to indoor nitrogen dioxide levels of roughly $30 \mu\text{g}/\text{m}^3$ (0.015 ppm), although average concentrations of $100 \mu\text{g}/\text{m}^3$ (0.050 ppm) have been recorded in some homes. (Health Canada, 1989)

iii) Aldehydes

- Aldehydes can be produced when combustion appliances are not properly adjusted. Primary indoor sources are gas stoves, space heaters and tobacco smoke. Identities of all the aldehydes produced during incomplete combustion of organic fuels are not yet known, but measurements in indoor locations have shown that formaldehyde, acetaldehyde and acrolein are the major aldehydes present. Concentrations of acrolein indoors range from 2 to $50 \mu\text{g}/\text{m}^3$ (0.001 to 0.02 ppm). Limited data indicate that levels of acetaldehyde average about $17 \mu\text{g}/\text{m}^3$ and range from 1 to $48 \mu\text{g}/\text{m}^3$. (Health Canada, 1989)

iv) Polycyclic Aromatic Hydrocarbons

- Polycyclic aromatic hydrocarbons (PAHs) are products of combustion, and are among a class of compounds known as semivolatile organic compounds (SVOCs) that have vapour pressures between about 10^{-2} and 10^{-8} kPa. (Wallace, 2001) Most PAHs are non-volatile solids that are very insoluble in water. They are frequently adsorbed onto the surfaces of particulates, and over 100 PAHs have been detected in airborne particulate matter. (Health Canada, 1989) Benzo- α -pyrene, a carcinogenic PAH, is present in diesel exhaust, tobacco smoke, and combustion exhaust from a wood burning fireplace. (Wadden and Scheff, 1983) (Samet and Cohen, 1999)

2.3.9.2 *selected evidence suggesting adverse respiratory effects*

i) Death

- An accumulation of carbon monoxide may result in a varied constellation of symptoms deriving from the compound's affinity for

and combination with hemoglobin, forming carboxyhemoglobin (COHb) and disrupting oxygen transport. Sufficient exposure has caused death by asphyxiation, for example, when furnace pipes leak or extensive backrafting occurs. The elderly, the fetus, and persons with cardiovascular and pulmonary diseases are particularly sensitive to elevated CO levels. (American Lung Association *et al.*, 1994)

ii) Cancer

- There is direct evidence that occupational exposure to polycyclic aromatic hydrocarbons (PAHs) entails an increased risk of contracting lung and bladder cancer. The risks of lung and bladder cancer were determined to be dose dependent when PAHs were measured quantitatively and truly nonexposed groups were chosen for comparison. The current threshold limit value of 0.2 mg/m³ of benzene soluble matter (which indicates PAH exposure) involves a relative risk after 40 years of exposure of 1.2-1.4 for lung cancer and 2.2 for bladder cancer. (Mastrangelo *et al.*, 1996) PAHs have been shown to be immunosuppressive with respect to IgM antibody response to the thymus-dependent antigen SRBC within two days after exposure. (Dean *et al.*, 1983)

iii) Respiratory Symptoms

- Carbon monoxide's primary effects are due to its limitation of oxygen delivery to body tissues, and include cardiovascular effects, neurological effects, and effects on the skin and skeletal muscles. It can also have respiratory effects such as pulmonary edema and upper respiratory tract irritation, wheezing, bronchial constriction and persistent cough. (American Lung Association *et al.*, 1994)
- Exposure to nitrogen dioxide can also cause respiratory symptoms. A recent study in Australia measured NO₂ levels in 80 homes in Victoria using passive samplers. Health outcomes for children were studied using a respiratory questionnaire, allergy testing and peak flow measurements. Respiratory symptoms were more common in children exposed to a gas stove, with an odds ratio (OR) of 2.3. Nitrogen dioxide exposure was a marginal risk factor for respiratory symptoms, with a dose response association present. Gas stove exposure was a significant risk factor for respiratory symptoms, suggesting an additional risk apart from the average nitrogen dioxide exposure. (Garrett *et al.*, 1999)

- In an outbreak of acute respiratory illness among adolescent ice-hockey players in an indoor ice arena in Stockholm, it was determined that the illness was likely due to a high level of nitrogen dioxide that resulted from poor ventilation and a malfunctioning ice-surfacing machine. Levels of nitrogen dioxide up to 2358 $\mu\text{g}/\text{m}^3$ (1250 ppb) were detected during simulated conditions of the incident with a propane ice-resurfacing machine. A study comparing exposed players to reference players who played in arenas with electric ice-surfacing machines showed that 55 subjects (55.6%) in the exposed group experienced acute respiratory symptoms compared to 4 (7.1%) of the reference group. The relative risk for the exposed group was 7.8 with a 95% confidence interval of 3.0 to 20.3. (Rosenlund *et al.*, 2000)

iv) Asthma

- An examination of a panel of 164 adult asthmatics in the Denver, Colorado Metropolitan area showed that indoor sources of combustion have a statistically significant association with exacerbations of asthma. In the study, the reported use of a gas stove was associated with moderate or worse shortness of breath (odds ratio OR 1.60), moderate or worse cough (OR 1.71), nocturnal asthma (OR 1.01), and restrictions in activity (OR 1.47). (Ostro *et al.*, 1994).
- In a European study of 125 self-reported asthmatics, daily personal exposures to nitrogen dioxide (NO_2) at home were associated with asthma symptoms in children. (Smith B.J. *et al.*, 2000) After adjustment for potential confounders, significant interactions for children of age less than or equal to fourteen years were demonstrated between NO_2 and the symptoms of:
 - Chest tightness on the same day (odds ratio (OR) 1.29, 95% CI 1.16-1.43)
 - Chest tightness with a one-day lag (OR 1.29, 95% CI 1.14-1.46)
 - Breathlessness on exertion with a one-day lag (OR 1.13, 95% CI 1.00-1.28)
 - Daytime asthma attacks on the same day (OR 1.13, 95% CI 1.02-1.26)
 - Night asthma attacks on the same day (OR 1.16, 95% CI 1.03-1.30)
 - Night asthma attacks with a one-day lag (OR 1.15, 95% CI 1.03-1.29)

For adults between 35 and 49 years, a significant association was demonstrated between NO_2 and coughs with a one-day lag (OR 1.15). (Smith, B.J. *et al.*, 2000)

- Combustion products on outdoor air (sulfur dioxide and nitrogen oxides), which can also enter the home, have been associated with self-reported asthma exacerbations in conjunction with cold symptoms

during the spring to fall period (March-November) in Vancouver, B.C. (Tarlo *et al.*, 2001)

- In a case-control study carried out in Montreal, Quebec between 1988 and 1990, indoor environmental factors were studied in relation to the incidence of asthma among 3- and 4-year-old children. In a subsample chosen to wear a nitrogen dioxide monitoring badge for a 24-hour period, there was a dose-response relationship between nitrogen dioxide (in parts per billion) and asthma. (Infante-Rivard, 1993)

v) Lung Function

- A study of lung function of adolescents and gas cooking was also undertaken in the Latium region in Central Italy. There was a significant reduction in lung function in girls exposed to gas cooking who also had high levels of the immunoglobulin IgE (a marker of allergic susceptibility). No significant deleterious effects were observed in girls with a low IgE value or in boys with either a low or high IgE. The researchers note that they do not know whether serum IgE is a simple indicator that an inflammatory process is in progress, or whether it is involved in the pathogenesis of injury leading to bronchial constriction. (Corbo *et al.*, 2001)
- Experimental studies in which human volunteers were exposed acutely to moderate levels of NO₂ have shown little evidence of lung inflammation or decreased host resistance capacity. Epidemiological studies, on the other hand, suggest that children living in homes with unvented heating sources are more prone to respiratory infections than children living in homes with lower levels of NO₂. (Devlin *et al.*, 1999) In a study to further investigate the effects of NO₂ on the human lung, Devlin and colleagues performed bronchoalveolar lavage on 8 healthy subjects who were exposed to 2.0 ppm NO₂ and to filtered air for 4 hours while undergoing intermittent moderate exercise. No changes in lung function were observed, but the aerosol bolus recovery technique revealed a statistically significant ($p < .05$) decrease in the fraction of aerosol recovered following nitrogen dioxide exposure, which is suggestive of small obstructive changes induced by NO₂. (Devlin *et al.*, 1999)

vi) Irritation

- The major effect of airborne aldehydes is irritation of the eyes, nose and throat. (Health Canada, 1989)

2.3.9.3 summary of selected evidence

The evidence cited suggests an association between combustion product exposure in housing and various adverse respiratory health effects, including:

- **exacerbation of asthma**
- **increased respiratory symptoms**
- **irritation of the upper respiratory tract**
- **decreased lung function**
- **risk of development of lung cancer**
- **death (only in the case of carbon monoxide overdose due to faulty combustion devices)**

2.3.9.4 remedial action to avoid exposure

Some of the remedies most often chosen to reduce health effects from combustion products indoors are:

- **Maintain furnaces properly and adjust for complete fuel combustion**
- **Inspect furnace pipes for cracking and leakage regularly**
- **Provide adequate fresh air supply for all interior combustion appliances to avoid backdrafting**
- **Install and maintain appropriate carbon monoxide and smoke detectors** (Yoon *et al.*, 1998)
- **Ensure that furnace exhaust outlets are remote from other pipes allowing air into a home (e.g. dryer exhaust port)**
- **Maintain and operate fireplaces and wood stoves properly, and inspect for combustion spillage**
- **Maintain proper kitchen exhaust particularly during oil frying, broiling and other smoke-generating activities**
- **Keep doors between garages and living spaces closed and well weather-sealed.**
- **Avoid operation of unvented fuel-fired heating appliances indoors (e.g. kerosene heaters, etc.)**
- **Keep outdoor barbecues sufficient distance from the home and close adjacent windows**
- **Maintain adequate exhaust ventilation over gas stoves during operation**
- **Ventilate well during any renovations requiring fuel combustion, e.g. propane or acetylene-fired plumbing torches**
- **Pipe automobile or truck exhaust to the exterior if a garage is being used for repairs and testing.**
- **Choose candles carefully to avoid lead and other metals in the wick or excess soot (test candles before using) and do not leave candles unattended.**
- **Avoid all smoking of tobacco or other products indoors**
- **Maintain adequate ventilation during self-cleaning oven cycles.**

Homeowners and tenants need to be alert for conditions which would lead to carbon monoxide leakage or reentrainment of combustion products into the home

through chimney backdrafting, intake of exhaust fumes through vents and windows adjacent to furnace exhausts, and combustion leakage from fireplaces and wood stoves. Proper sealing between living spaces and garages is also important, as is attention to the dangers of unvented combustion heaters.

Gas stoves are ubiquitous in Canadian homes and have been accepted for generations as safe appliances for cooking. While the level of risk of respiratory symptoms has not been well researched, it is clear that gas stoves do pollute indoor air, sometimes quite heavily, and that the products of combustion (carbon monoxide, nitrogen dioxide, and some aldehydes) can be hazardous to respiratory health. Sensitive individuals may need to consider increasing ventilation over a gas kitchen range, or replacing it with an electric range.

2.3.10 Products of Emission

2.3.10.1 nature of the contaminant and its sources

This category includes gases and particles emitted from building materials, furnishings, clothing, appliances, cleaning materials, personal hygiene products, maintenance materials and other household items (e.g. newspapers).

i) Volatile Organic Compounds

- Volatile organic compounds (VOCs) are emitted as gases from certain solids or liquids at room temperature. Compounds are included in this category if they have vapour pressures greater than about 10^{-2} kPa. (Wallace, 2001) They include chemical compounds such as aliphatic hydrocarbons, alkylated aromatic hydrocarbons, chlorinated hydrocarbons, ketones, aldehydes and benzene.
- Sources of VOCs indoors include paint, floor sealant and vinyl, furnishings, cleaning products, solvents, waxes, hygiene products, perfumed soaps, drycleaned clothing, detergents and deodorizers, and hundreds of other household items from newspapers to children's toys. Most indoor air environments demonstrate VOC concentrations that are one hundredth to one thousandth of the current acceptable exposure limits established to protect health and performance in the workplace. (Indoor VOC concentrations in most indoor environments rarely exceed 1 mg/m^3 , except during and immediately following construction.) (Burton, 1997)

- VOCs are ubiquitous in the environment. Rural outdoor samples can contain 50 to 100 VOCs at levels on the order of 0.01 to 1 part per billion by volume (ppbv). Indoor air samples can contain twice as many VOCs at levels several times higher than outdoors. New buildings contain some airborne VOCs at concentrations that are 100 times outdoor levels, and levels fall to 10 times the outdoor level about 2 to 3 months later. Human exposure to most VOCs is through inhalation, although some VOCs are ingested in food, beverages and drinking water as contaminants. Some VOCs may travel in groundwater or through soil from hazardous waste sites, landfills, or gasoline spills. (Wallace, 2001)

ii) Formaldehyde

- Formaldehyde is a volatile organic compound that is a characteristic emission from carpeting, particleboard or waferboard, some home furnishings and new clothing. It is a colourless gas with a pungent odour, and it combines readily with water to form a non-volatile compound. It has a tendency to be absorbed onto surfaces and textiles, such as carpets and curtains. An equilibrium is established between formaldehyde in air and that adsorbed on surfaces and contained within wood products such as particleboard. (Health Canada 1989)

2.3.10.2 selected evidence suggesting adverse respiratory effects

i) Cancer

- Some volatile organic compounds present in indoor air are considered to be human carcinogens (e.g. benzene and vinyl chloride). Some have been identified as animal carcinogens and may be human carcinogens (e.g. methylene chloride, trichloroethylene, tetrachloroethylene, chloroform, and *p*-dichlorobenzene). Some are known as weak animal carcinogens (e.g. limonene). (Wallace, 2001)
- The occupational setting has been better studied than the residential setting in terms of cancer risks. For example, occupation as a painter, which can involve considerable organic solvent exposure, has been associated with a 40 percent increased risk of lung cancer. With the mixed exposures it has not been possible to identify the specific causative agent(s). (Lynge *et al.*, 1997) Extrapolation from this experience to residential solvent exposures is difficult, however, since a

painter's solvent exposure would be considerably in excess of normal residential indoor exposures.

- Wallace calculated that there are only six VOCs that exceeded the negligible lifetime cancer risk level of 10^{-6} (one in a million chance of contracting cancer) by a factor of ten or more. These are benzene, vinylidene chloride, *p*-dichlorobenzene, chloroform, methylene chloride, and carbon tetrachloride. (Wallace, 2001)
- Of these, benzene is the only one considered to be a human carcinogen and the only compound with human epidemiological studies showing a possible influence of residential environmental levels of benzene exposure on cancer risk, through benzene's presence in tobacco smoke. (Wallace, 2001) In these studies, leukemia was reported in the children of smokers at twice the rate of leukemia in children of non-smokers (Sandler *et al.*, 1985) (Stjernfeldt *et al.*, 1986).
- Benzene is a hematotoxin, with the absolute lymphocyte count being the most sensitive indicator of benzene-induced hematotoxicity. (Rothman *et al.*, 1996) A causal association between exposure to benzene and an increased risk of leukemia is also well-established. (Lynge *et al.*, 1997) There were no associations found in the literature between benzene and lung cancer other than a study of almost 75,000 workers in China exposed to benzene industrially during 1972-1987. The benzene-exposed workers had a small increase in lung cancer mortality (relative risk = 1.2) compared to unexposed workers. (Yin *et al.*, 1996)
- Formaldehyde is considered to be a potential upper respiratory carcinogen, based on studies in which nasal cancer was induced in test animals. (Swift and Foster, 1999) (Manuel, 1999).

ii) Asthma

- Jaakkola *et al.* concluded in a Finnish study that the risk of asthma in children was increased for children exposed to plastic wall materials in homes (odds ratio 1.52). This population-based cross-sectional study involved 2568 Finnish children aged 1 to 7 years. (Jaakkola *et al.*, 2000).
- Some information relevant to VOC exposures and asthma in the residential setting is available from research in an occupational setting. A recent study among Spanish indoor cleaners investigated asthma risk and the connection with cleaning activities and the use of specific cleaning products. In the group studied (67 cleaners), asthma prevalence

was 1.7 times higher than among a reference group, and was highest among private home cleaners (OR 3.3). More than half of the cleaners reported work-related respiratory symptoms. Asthma in home cleaners was mainly associated with kitchen cleaning and furniture polishing, with the use of oven sprays and polishes. (Zock *et al.*, 2001) While exposure of individuals who clean for a living may be in excess of that of a householder who does his or her own cleaning, the types of cleaning compounds and therefore the emissions involved can be very similar.

- The water-based paints frequently used for house painting still contain small amounts of volatile organic compounds (VOCs), with the potential to exacerbate symptoms of asthma. Because of these potential problems and environmental concerns, some manufacturers have produced paints with no VOC content. In a study to compare the effects on asthmatics of conventional water-based paint and the new VOC-free paint, seventeen asthmatics were recruited on the basis of having previously reported exacerbation of symptoms by paint or other odours. Each undertook a standard painting task with identically coloured conventional acrylic and VOC-free paints in a double-blind, crossover study. Respiratory symptoms, lung function, and airway responsiveness were measured at each visit. A significant increase in reported “wheeze” was detected during use of conventional paint ($p < 0.01$), but not with the new paint. There was also a significantly greater increase in reported “breathlessness” whilst using conventional paint than with the new paint ($p < 0.05$). In contrast, lung function measurements showed a small but significant increase during the use of both paints ($p < 0.05$). There was no significant change in airway responsiveness after use of either paint. The new paint appears to be less likely to cause a worsening of respiratory symptoms than conventional acrylic paint, although this difference is not reflected in measurements of lung-function or airway responsiveness. (Beach *et al.*, 1997)

iii) Pneumonia

- Jaakkola *et al.* concluded in the Finnish study cited above that the risk of pneumonia was also increased in children exposed to plastic wall materials (odds ratio 1.82). (Jaakkola *et al.*, 2000)

iv) Wheezing and Cough

- The Jaakola study of 2568 Finnish children indicates that there may be respiratory effects even at the very low VOC levels which would be associated with plastic wall materials. The study demonstrated that lower respiratory tract symptoms were strongly related to the presence of plastic wall materials, whereas upper respiratory symptoms were not. Lower respiratory symptoms studied included persistent wheezing (odds ratio OR 3.42), cough (OR 2.41) and phlegm (OR 2.76). (Jaakkola, *et al.*, 2000)

v) Respiratory Irritation

- Respiratory symptoms of VOC exposure can include upper respiratory irritation and dyspnea (difficulty breathing). (American Lung Association *et al.*, 1994)
- A randomized, crossover-design trial of controlled human exposures to filtered air for four hours, to VOCs at 25 mg/m³ for four hours, and VOCs at 50 mg/m³ for four hours, using a VOC mixture based on sampling of indoor environments, was conducted on subjects chosen to be without bronchial hyperresponsiveness. The VOC exposures caused a dose-related increase in lower respiratory, upper respiratory and non-respiratory symptoms, with no significant changes in several lung function parameters and biomarkers of inflammation. Atopic individuals had significantly reduced lung function as measured by FEF (25-75) following exposures to VOCs at 50 mg/m³, suggesting that these individuals may be more sensitive to the health effects of VOCs. (Pappas *et al.*, 2000)
- Airborne formaldehyde acts as an irritant to the conjunctiva and upper and lower respiratory tract. (Manuel, 1999) Symptoms are temporary, and, depending upon the level and length of exposure, may range from burning or tingling sensations in eyes, nose and throat to chest tightness and wheezing. Acute, severe reactions to formaldehyde vapour may be associated with hypersensitivity. It is estimated that 10 to 20 percent of the U.S. population, including asthmatics, may have hyperreactive airways which may make them more susceptible to formaldehyde's effects. (American Lung Association *et al.*, 1994)
- An Australian study examining the effects of formaldehyde in homes on children 7-14 years of age, higher formaldehyde levels were associated with more frequent symptoms among children suffering from

respiratory symptoms. There was no significant increase in the risk of asthma or respiratory symptoms with formaldehyde exposure, but the study did establish an association between formaldehyde exposure and allergy (odds ratio 1.40 with 95% confidence level 0.96-2.00 at an increase in bedroom formaldehyde levels of 10 $\mu\text{g}/\text{m}^3$. (Garret *et al.*, 1999b)

- A relationship between VOC exposure and sick building syndrome is not proven but often suspected because VOCs are found at higher concentrations in indoor air (compared to outdoors), are irritants at high concentrations, and complaints about indoor air are typically more prevalent in new or remodeled buildings when VOC concentrations are highest. (Burton, 1997)

vi) Airway Inflammation

- In a study assessing the respiratory health aspects of the indoor air quality in 12 randomly selected primary schools in Sweden, a standardized investigation was undertaken which included an assessment of inflammatory indicators in nasal lavage (NAL), measurement of the nasal cavity by acoustic rhinometry, and hygienic measurement of airborne pollutants. Most of the classrooms measured (83%) did not meet Swedish ventilation standards. In the study, the presence of formaldehyde was associated with a lower degree of nasal patency, and an increase of eosinophil cationic protein (ECP) and lysozyme in nasal lavage fluid (indicators of inflammatory response in the nasal mucosa). (Norback *et al.*, 2000b)

2.3.10.3 summary of selected evidence

The evidence cited suggests an association between exposure to products of emission in housing and various adverse respiratory health effects, including:

- **exacerbation of asthma**
- **increased respiratory symptoms including wheezing and cough**
- **irritation of the upper respiratory tract**
- **inflammation of the airways**
- **decreased lung function**
- **increase in allergic sensitization**
- **increase in risk of pneumonia**
- **risk of development of lung and other forms of cancer (e.g. from benzene exposure)**

Most information in the literature regarding the toxicology of VOCs has been obtained from animal studies at intolerably high concentrations for humans, or

exposures to humans in industrial environments. (Burton, 1997) There is not much information available about the effects of longer term exposure to emission products at very low levels. However, it is known that prolonged exposure even to very low concentrations of chemical contaminants may result in delayed toxic effects. (Health Canada, 1989)

2.3.10.4 remedial action to avoid exposure

In general, the remedies most often chosen to reduce health effects from products of emission within buildings are:

- **Choose lower-emission products**
- **Increase initial and/or subsequent general ventilation**
- **Introduce spot ventilation at the emission source**
- **Contain the emitting surface or product**
- **Segregate the emitting surface or product**
- **Improve building design details, e.g. to avoid air leakage**

While the reductions in exposure possible from these remedies are in some case obvious or common sense, there is also some evidence supporting the efficiency of some of them.

For example, a recent study in Finland provided limited evidence that indoor air quality can be improved by careful design, choice of proper materials and equipment, and high quality construction, combined with initial and subsequent ventilation. In this particular study a one-week new-building ventilation period reduced the levels of total volatile organic compounds by 50%. (Tuomainen *et al.*, 2001)

Cabinets made of particleboard or medium-density fiber board (MDF) manufactured from urea-formaldehyde resin can be sources of formaldehyde and other organic compounds. If particleboard or MDF are used, all surfaces and edges should be laminated to encapsulate the emissions. Alternatively, several coatings of a low-odor acrylic sealant can be used. Composite wood in substrate applications such as flooring system reinforcement is also a potential source of formaldehyde and other VOCs. Other subfloors such as construction-grade plywood, manufactured with phenol-formaldehyde resin, have lower formaldehyde emissions than does particleboard or MDF. (American Thoracic Society, 1997)

There are many household products that contribute to elevated VOC levels, including cleaning agents, polishes, paints, deodorizers, mothballs, personal care products, adhesives, craft materials, and many other products. The American Thoracic Society Workshop concluded that despite the lack of data establishing that these products cause particular health symptoms, minimizing exposures to

potentially harmful constituents is recommended. This may be achieved by substitution of different products or product selection by the consumer, elimination of perfumes from products, and the provision of appropriate use conditions for the products. (American Thoracic Society, 1997) In most cases there are practical alternative materials or cleaning and maintenance methods that will accomplish the same purpose or task without hazardous emissions.

Likewise, exposures from crafts in the home can be reduced by using materials in well-ventilated spaces. Housekeeping practices are critical for avoiding dust from hobbies. Exhaust ventilation should be considered for pottery kilns in the home. Emissions from home office equipment can be minimized by direct venting, segregation of equipment to isolate it from workers, and selection of lower-emitting products. (American Thoracic Society, 1997)

2.3.11 Particulate Matter

2.3.11.1 nature of the contaminant and its sources

- Some of the categories above (e.g. dust mites, combustion products) include contaminants that are particulate in nature. Particulate matter can also be considered a category in themselves. Particles are usually divided into three categories by size: those greater than 2.5 microns are usually called coarse particles, and those less than 2.5 microns are called fine particles. (McDonald and Ouyang, 2001) Particles less than 0.1 microns are called ultrafine particles. (Fogarty and Nelson, 2001)
- Particles are often categorized according to their ability to penetrate into the human respiratory system. *Inhalable* dust is a term used to describe dust that is hazardous when deposited anywhere in the respiratory tree including the nose and the mouth (50% cut-point* of 100 μ). Particles in the regions of 7-20 μ will penetrate to the bronchioles and are called *inspirable* or *thoracic* (50% cut-point of 10 μ). Particles in the size range 0.5-7 μ , which can penetrate to the nonciliated portion of the gas exchange region of the lungs (the alveolar region) are called respirable (50% cut-point of 4 μ). (*In these definitions “cut point” describes the performance of particle size selective sampling devices. For personal sampling, the 50% cut point is the size of the dust that the device collects with 50% efficiency.) (SafetyLine Institute, 1998)
- Human exposure to particulates is typically separated into outdoor exposures (part of “ambient air pollution”) and indoor exposures (commonly thought of as “dust”).

Particles *of outdoor origin* can also be distinguished from particles *of indoor origin*. This report is concerned primarily with the effects of indoor particulate exposures, whether the particulate origin is indoors or outdoors.

i) Particles Found Indoors

- A recent study reported in Norwegian literature investigated airborne house dust particles in Oslo, Norway. The researchers used transmission electron microscopy to quantify and characterize airborne house dust particles, with regard to elemental and size distribution. A vast majority of the airborne particles sampled were found to be less than 2.5 microns in diameter, which is a size capable of penetrating deep into the respiratory tree. This PM_{2.5} fraction contained, in addition to sulphur aerosols and silicates, many soot particles, most of them being less than 1 micron in diameter. These soot particles were found to carry allergens on their surface. The researchers also found that diesel exhaust particles, which they felt likely to be the main soot component of airborne house dust, absorbed several well-known allergens *in vitro*. (Ormstad, 2001)
- Actual personal exposures indoors may exceed indoor particle concentrations. A California study found that population-weighted daytime personal PM₁₀ exposures averaged 150 +/-9 µg/m³, compared to concurrent indoor and outdoor concentrations of 95 +/-6 µg/m³. The authors describe this excess mass near the person as a “personal cloud” that appeared to be related to personal activities. (Ozkaynak *et al.*, 1996)
- Another study hypothesizes that this personal exposure discrepancy is due to a ‘proximity effect’ whereby people are exposed to more concentrated particles in the immediate vicinity of a pollutant source. In this experiment there was a source proximity effect from a burning incense stick for the fine particle sizes (0.3 to 2.5 microns) and particle-bound PAH (polycyclic aromatic hydrocarbons) up to at least 1.0 meter from the source. (McBride *et al.*, 1999)

ii) Particles of Indoor Origin

- Recent studies using sophisticated particle-size analyzers have shown that combustion events in the home also produce abundant quantities of ultrafine particles (<0.1 µm) which can penetrate lungs deeply. (American Thoracic Society, 1997)

iii) Particles of Outdoor Origin

- Particles of outdoor origin can be encountered outdoors or indoors. The exposure of people to such particulate contaminants indoors depends partly on the nature of the building they live or work in. Buildings with considerable air leakage provide less protection from outdoor smog episodes than those that are airtight and that filter intake air.
- Ambient air includes a relatively stable suspension of finely divided liquid and solid particles that may be inhaled and deposited in the respiratory tract. In city air, these airborne particles may consist of such materials as ammonium sulfate and ammonium nitrate salts formed from pollutant gases, clay and soil particles suspended from the ground, small droplets of water and organic materials, fibers from industrial processes, carbon and fly ash from combustion processes, metallic compounds, and other types of particulate material either released into or formed from the ambient air. (Raabe, 1999)
- A wide range of particle sizes and types and a variety of chemical forms may be present in polluted air. For example, some PM₁₀ airborne particles (the mass concentration measure of outdoor suspended particulates less than or equal to 10 microns) may be quite acidic, containing relatively high levels of biologically reactive sulfuric acid or nitric acid that contribute to adverse lung responses. In other situations PM₁₀ may consist of relatively inert wind-blown dust. In still other situations, the PM₁₀ may include levels of potentially toxic metallic compounds. Such particles may also adsorb other acidic and oxidant chemicals formed in air pollution episodes. (Schwartz, 1994 and 1996)

2.3.11.2 selected evidence suggesting adverse respiratory effects

- There is strong evidence linking levels of outdoor PM₁₀ and PM_{2.5} particles to an increase in respiratory symptoms, episodes of asthma, and respiratory and cardiac mortality. (Committee of the Environmental and Occupational Health Assembly of the American Thoracic Society, 1996) Canadian data indicates that daily mortality increases linearly as concentrations of particles increase for persons who have acute lower respiratory diseases, chronic coronary artery diseases (especially in the elderly), and congestive heart failure. (Goldberg, Burnett *et al.*, 2001) It is assumed for this study that encountering outdoor particulates indoors entails some of the same risks as have been established in outdoor air pollution studies. In addition, lung compromise or damage due to

outdoor air pollution may increase susceptibility to irritation or exacerbation of existing disease by exposure to indoor pollutants.

i) Allergic Immune Response

- In Ormstad's study of airborne house dust particles in Oslo, Norway, the airborne house dust particles were found to elicit a local lymph node inflammatory response, and to have an adjuvant activity on the production of IgE antibodies to ovalbumin as a model allergen. (Ormstad, 2001) Ormstad concluded that airborne house dust particles may contribute to an allergic immune response, and thereby also to asthma and allergic diseases.

ii) Inflammation of the Airways

- When inhaled, airborne particles of either outdoor or indoor origin are deposited when they come in contact with the various surfaces of the respiratory tract. Particle disposition may lead to injury or other biological responses. Inhaled airborne particles may include particles as large as 100 microns (μm) in diameter, although such large particles are not likely to reach the lung. Particles smaller than about 10 microns in diameter are more likely to enter the lung during inhalation. Because of the high permeability of the lung and the copious blood flow, relatively soluble materials depositing in the lung can readily enter the blood for distribution throughout the body; other less soluble particles can directly influence the airway epithelium, cause cellular damage, and effect responses via various airway receptors. (Raabe, 1999)
- Similarly, the involvement of diesel exhaust particles in respiratory diseases was evaluated by another research group by studying their effects on two *in vitro* models of human airway epithelial cells. The results suggest that diesel exhaust particles can be phagocytosed by airway epithelial cells and that they can induce a specific inflammatory response. Some of the inflammatory effect depended on the content of adsorbed organic compounds, rather than the carbon black component of the particles, and exhaust gas post-treatments which diminished the adsorbed organic compounds reduced some of the inflammatory effect. (Boland *et al.*, 1999).

iv) Asthma

- PM_{10} , which are those particles available for deposition in the human lung during inhalation, is considered to be a good indicator of inhalation risks for asthma. Recently emphasis has been placed on measuring the fine particle fraction, usually defined as consisting of airborne particles smaller than 2.5 microns in diameter, or $PM_{2.5}$. The U.S.EPA currently believes that the fine particle fraction is a better indicator of inhalation risks associated with observed increased in mortality and morbidity rates. (Raabe, 1999)

2.3.11.3 summary of selected evidence

Much of the data on health effects due to particulate exposure is related to particulates and other air pollutants found outdoors. There is strong evidence linking outdoor PM_{10} and $PM_{2.5}$ to an increase in respiratory symptoms, episodes of asthma, and respiratory and cardiac mortality. (Committee of the Environmental and Occupational Health Assembly of the American Thoracic Society, 1996) Some of the data gathered in this manner may be relevant to indoor particulate exposure, due to similarities in particle size and composition.

The evidence cited above suggests an association between exposure to indoor particulates and various adverse respiratory health effects, including:

- **exacerbation of asthma**
- **inflammation of the airways**
- **increase in allergic immune response**

Indoor particulates also contain compounds and allergens that were generated indoors, including contaminants like polycyclic aromatic hydrocarbons (PAHs) from wood fireplaces, allergens from household pets, mould spores grown on damp building materials with the help of basement water leakage, and any of hundreds of combustion products arising from tobacco smoking. Health effects of many of these exposures have already been described in earlier sections, and vary from exacerbation of asthma to increased risk of lung cancer.

2.3.11.4 remedial action to avoid exposure

People with cardiac or respiratory illnesses have often been advised to avoid going outdoors during periods of high air pollution and smog. How efficient a home is in protecting from particulates of outdoor origin will depend on the tightness of the home and the nature, if any, of filtration of intake air. New building technologies (e.g. air-sealing insulation and energy recovery ventilators) are enabling the design

and construction of tight buildings with filtered air intake which are much more protective from smog exposures than previous types of buildings.

Indoor air particles can be reduced by aggressive dust control programs, which may include removing curtains and carpeting, which can harbour small particles easily. Use of high-performance vacuum cleaners or central vacuums can also reduce dust accumulation without adding to the fine particle fraction in the air. Air cleaners can be helpful, depending on what size particles they are designed to capture, how efficient their capture rate is, and how much air flows through the unit. However, they may not address heavier particles which settle out of the air readily but become airborne easily when a carpet or piece of furniture is disturbed.

One of the most effective strategies to avoid health effects from particulates found indoors is to reduce the hazardous content of airborne and deposited household dust. Many of these components have already been discussed in earlier sections, including mould spores, dust mites, insect and animal allergens, bacteria, bacterial endotoxin, tobacco smoke, and exhaust from leaky furnaces or fireplaces. Some households also maintain a “no shoes” policy to ensure that outdoor particulates from soil and road dust do not get tracked throughout a home.

2.3.12 Other Specific Contaminants:

2.3.12.1 nature of the contaminant and its sources

There are many other specific contaminants found indoors that may also increase the risk of respiratory illness. Among the most significant are ozone (from electronic air cleaners, ozone generators, and home office laser printers), chlorine (from chlorinated tap water and use of laundry bleach), radon (from soil gases) and pesticides (from indoor pest control treatment and from tracking in from outside on shoes). In the current review only a cursory look at this category has been undertaken.

i) Ozone

- Ozone is a very reactive compound (O₃) easily generated in highly toxic concentrations in air passing through an electrostatic field. Unreacted ozone at the relatively low concentration of 120 ppb can cause eye irritation, visual disturbances, headaches, dizziness, dry mouth and throat, chest tightness, insomnia, and coughing. (Underhill, 2001) Indoors the most common source of ozone is the electrostatic precipitator, a dust removal device usually attached to a furnace.

Properly designed, installed and maintained electrostatic precipitators produce ozone levels that are relatively low compared to levels acceptable for exposure to healthy human beings. Malfunctioning or infrequently cleaned units may produce more ozone. (McDonald and Ouyang, 2001) Ozone generators have been used ostensibly to scavenge odoriferous organic compounds, but the rate of reaction with such compounds is relatively low and the reaction products thus formed are often less desirable than the unreacted compounds. For example, the reaction products of ozone with toluene include aldehydes that have a far more unpleasant odor, and are far more toxic, than the parent compound toluene. (Underhill, 2001)

ii) Radon

- Radon (^{222}Rd) is a noble and inert gas resulting from the decay of naturally occurring uranium-238 (^{238}U). With a half-life of > 3 days, radon diffuses through rock and soil after it forms. In homes, the principal source is soil gas, which penetrates through cracks or sumps or around a concrete slab. Because ^{238}U is universally present in the earth, radon is a ubiquitous indoor air pollutant, and it is also present in outdoor air. Infrequently, building materials (e.g. concrete block, gypsum board) may also contribute significantly to indoor concentrations. Under most circumstances, public water supplies are not likely to be a source of radon. (Samet, 2001)
- The rate of infiltration of soil gas into the home varies with the strength of the “stack effect” and also with the interaction of wind with the walls and the roof. There is substantial variation among radon concentrations in homes, with some regions having few homes with high levels, and others having many homes with high levels. This heterogeneity reflects both soil and housing characteristics. Homes with basements have the greatest potential for higher concentrations. (Samet, 2001)

iii) Chlorine

- Chlorine and chlorinated compounds can be present in indoor air due to the presence of chlorine as a disinfectant in the drinking water supply, due to the use of chlorinated products in laundry activities (e.g. Chlorine bleach) and in indoor pool and hot tub disinfection. The use of chlorination for disinfecting public swimming pools leads to chloroform levels in air in the range of 2.5-54 ppm, which is as much as 500 times

typical outdoor levels. (Brauer, 2001) Domestic washing machines play a role in volatilizing and dispersing chlorine compounds from laundry bleach and from potable water supplies. (Howard and Corsi, 1998)

iv) Pesticides

- A pesticide is any substance used to control, repel or kill a pest (insect, weed, fungus, rodent, etc.) Pesticides encompass a very large and diverse group of substances. Pesticides may be simple inorganic substances such as sulfur, chlorine, chlorine oxide, arsine, copper arsenate, and potassium bromide; organometallic compounds such as zinc bis(dimethyldithiocarbamate); volatile organic compounds (VOCs) such as carbon tetrachloride, methyl bromide, 1,4-dichlorobenzene, and naphthalene; semivolatile organic compounds (SVOCs) such as diazinon, chlorpyrifos, pentachlorophenol, and propoxur; or nonvolatile organic compounds (NVOCs) such as 2,4-dichlorophenoxyacetic acid (2,4-D), dimethylamine salt, and permethrin. There are multiple circumstances in the home environment in which pesticides are commonly used. (Lewis, 2001)
- Pesticides may be periodically introduced into indoor air by direct application (e.g. insect sprays and bombs, disinfectant sprays, room deodorizers). In addition, there are often sources that continually emit vapours into the living space (e.g. Continuous evaporation of residues from crack and crevice treatments, emissions from pest control strips). Whether used inside the home, or outside on the lawn or garden, pesticides accumulate on indoor surfaces, especially in carpet dust. Insecticides and disinfectants applied indoors may persist for extended periods, protected from sunlight, rain, temperature extremes, and most microbial action. Pesticides applied to the lawn or used in the garden may be tracked indoors, where they can persist for months or years, as opposed to days outside on the grass. Typically, pesticide concentrations in indoor air and house dust are 10 to 100 times those found in outdoor air and surface soil. (Lewis, 2001)
- Results from simultaneous 24 hour indoor air and personal exposure monitoring in a Non-Occupational Pesticide Exposure Study (NOPES) showed that 85 percent of the total daily adult exposure to airborne pesticides was from breathing air inside the home (Whitmore *et al.*, 1994) (Lewis, 2001)

2.3.12.2 selected evidence suggesting adverse respiratory effects

i) Irritation of the Airways

- As a relatively insoluble gas, ozone (O₃) generally imparts its greatest irritant action to the deeper reaches of the lung. However, its solubility in water is greater than that of oxygen and its oxidant nature renders it able to react with almost any biomolecule along the respiratory tract. The primary lung function effect of ozone in humans is a reduction in FVC and FEV₁, with no appreciable effect on standard lung volumes. These effects occur at 0.15 ppm for 2 hours with high levels or intermittent exercise or at 0.08 ppm for 6.6 hours with mild intermittent exercise. In addition to O₃-associated decreases in forced lung volumes, this oxidant can also induce airway hyperreactivity. This hyperreactivity is associated with inflammation that can not be blocked by anti-inflammatory drugs in humans or animals. Likewise, O₃-induced hyperreactivity does not adapt or diminish with repeated daily exposures. Because O₃ is not easily sensed during exposure, the potential for cumulative harm is greater than with inhalants with lower odor or sensory irritant thresholds. (Swift and Foster, 1999)
- Shusterman *et al.* observed augmented nasal congestive response after chorine exposure (0.5 ppm) in subjects with seasonal allergic rhinitis, compared with non-rhinitic subjects. (Shusterman *et al.*, 1998)

ii) Asthma

- Salome *et al.* compared the effects of standard and “low irritant” insecticide aerosols on lung function, airway hyperresponsiveness (AHR) and symptoms in asthmatic subjects who reported sensitivity to insecticide aerosols. They concluded that some standard insecticide aerosols trigger symptoms and falls in lung function in some people with asthma. They also concluded that these aerosols can increase airway hyperresponsiveness. The low irritant formulations did not have these effects. (Salome *et al.*, 2000)
- O’Malley described illness cases reported to the California Pesticide Illness Surveillance Program. These included asthma associated with exposure to contaminants in organophosphate insecticides. (O’Malley, 1997)

iii) Lung Cancer

- The concern about radon in the air of homes was initially driven by the strong evidence that radon causes lung cancer in underground miners. As the findings of epidemiologic studies of underground miners were reported from the 1950s on, there was soon substantial evidence that radon was a cause of lung cancer. (Samet, 2001)
- Radon is an alpha particle emitter which decays with a half life of 3.5 days to a short-lived series of progeny. Alpha decays of two radioisotopes in the decay chain, polonium-218 (^{218}Po) and polonium-214 (^{214}Po) deliver the energy to target cells in the respiratory epithelium that is considered to cause radon-associated lung cancer. Alpha particles, equivalent to a helium nucleus, are charged and have a high mass. Although their range of penetration into tissues is limited, they are highly effective in damaging the genetic material of cells. The passage of even a single alpha particle through a cell can cause permanent genetic damage. (Samet, 2001)

2.3.12.3 summary of selected evidence

The evidence that radon causes cancer is strong. Controversy surrounding radon exposure in homes centers on the costs and benefits of risk management strategies.

The evidence concerning the irritant effect of ozone is well studied with respect to outdoor exposures, particularly in conjunction with exercise. Respiratory effects indoors at exposure levels typically associated with emissions from electronic air cleaners have not been well studied. It is clear, however, that ozone is a very toxic compound. (Underhill, 2001)

There is some evidence of adverse respiratory effects on swimmers of long-term exposure to chlorinated compounds in swimming pools, and some documentation cited above concerning nasal congestion effects of experimental chlorine exposure. While there is documentation of emissions and exposure levels associated with chlorinated compounds in laundry products and drinking water, no reports were found during this study that deal with respiratory effects of these exposures.

The respiratory effects of pesticide exposures have been more extensively studied in the occupational environment (e.g. farmers) than in the home. Evidence that was found during this study indicates a potential association of some pesticide exposures with asthma. A more extensive search would be required to determine the applicability of this potential association to indoor pesticide exposure.

2.3.12.4 remedial action to avoid exposure

For homes requiring radon mitigation, there are a variety of control approaches, depending on the type of housing and the source of the radon. For preventing radon entry from soil, techniques include soil depressurization, sealing, building pressurization, and source removal. Radon in water can be removed with an activated carbon unit or aeration of the water before it is brought into the building. To remove radon after entry, ventilation and air cleaning represent the two principal approaches. (Samet, 2001)

There are viable alternatives to the use of chlorine bleach in the home. Adequate ventilation, particularly in bathrooms and laundry areas, is the primary mitigation method at the moment for reducing chlorinated hydrocarbon exposure from domestic water supplies. Some communities are shifting away from chlorination to other methods, including ozonation, which do not produce these compounds.

Use of integrated pest management methods and less toxic compounds for elimination of household pests can reduce exposure to higher toxicity pesticide compounds.

3 Conclusions

It would be ideal if all indoor exposures were supported by strong scientific evidence that establishes a definite causal link between the exposure and specific health effects. It would also be helpful if such evidence had been reproduced by multiple researchers over time. It would also be comforting if such conclusions had achieved a reasonable degree of medical and scientific acceptance and consensus.

Such is not the case. While much of the evidence is compelling, most of it establishes an association between an indoor environmental factor and respiratory illness, and not a confirmed causal connection. While this begs for further research in each area to unearth or confirm the actual causal mechanisms, it does not prevent practical action in the interim which could reduce the incidence of respiratory illness.

For example, it will be interesting and useful to ultimately learn the relative role of dust mites, moulds, bacteria, bacterial endotoxins and other agents in respiratory illness associated with dampness in housing. But it is possible without knowing all of the details, to make changes in housing that will avoid, reduce or eliminate dampness, and that will correspondingly reduce the risk of adverse respiratory health associated with it.

Likewise, eliminating dampness and extensive fungal exposure in housing would be safer (in terms of unknowns) and likely more effective than eliminating only *Stachybotrys chartarum* or bacterial endotoxin exposure. In this case, the action would be based on a strong general association (dampness in housing and respiratory illness), but would still assist in protecting people from specific hazards that may only later be proven to have definite causal connection to specific forms of illness. (e.g. *Stachybotrys chartarum* and pulmonary haemorrhage, bacterial endotoxin and development of asthma).

There have been a number of areas highlighted in this report where remedial measures could improve respiratory health:

- **reduction of dampness in housing and associated mould and bacterial exposures**
- **reduction of risk factors for the development of upper respiratory tract infections (which are important in the exacerbation of asthma)**
- **reduction of allergen exposures, including dust mites, cockroach antigen and animal dander**
- **reduction or elimination of exposure to environmental tobacco smoke**
- **avoidance or reduction of exposure to products of combustion**
- **reduction or avoidance of unnecessary exposure to products of emission**
- **reduction of exposure to particulates, especially PM10 and PM2.5**
- **reduction of exposure to radon and radon progeny through better building design**

There are several areas in which future research may yield better answers than are available at present:

- **the role of early infections, bacterial endotoxin and some allergen exposures in protection against the development of asthma later in life**
- **the role of particulate exposure indoors, including ultrafine particulates, in respiratory illness**
- **the potential for making houses and apartments more protective with respect to intrusion of outdoor pollutants by using better sealing and filtration technology**
- **the role of gas stoves in respiratory illness, and appropriate strategies for reducing risks associated with indoor use of gas**
- **the potential hazards of indoor pesticide contamination and appropriate alternatives to reduce exposure and health risk**
- **the potential respiratory hazards associated with chlorinated hydrocarbon compounds in potable water supplies.**

The Canadian Asthma Consensus Report (1999) provides physicians with current guidelines for the diagnosis and optimal management of asthma in children and adults. The report states that “respirologists, immunoallergists, pediatricians and emergency and family physicians gave prime consideration to the achievement and maintenance of optimal control of asthma *through avoidance of environmental inciters*, education of patients and the lowest effective regime of pharmacotherapy to reduce morbidity and mortality.” (Boulet *et al.*, 1999) It is hoped that this report will contribute to consumer knowledge about how to avoid exposure to such inciting agents in the indoor environment.

Finally, much of the knowledge acquired in the residential setting is also applicable, with minor extensions, in other non-occupational settings. For example, nitrogen dioxide has caused respiratory symptoms among children in hockey arenas as a result of exposure to the unvented exhaust gases from ice-surfacing machines. Similarly, cleaning products are responsible for exposure of children to volatile organic compounds in schools, and there are now practical alternatives to such products. In addition, the same mechanisms that lead to mould growth in housing (e.g. water leakage and air leakage leading to moisture condensation in walls) are responsible for mould growth in school buildings and portable classrooms. It is hoped that some of the information presented within this report may contribute to indoor air quality improvements in non-housing settings as well.

4 References

Access Excellence, the National Health Museum website, <http://www.accessexcellence.org/ae-bin/multisearch.cgi>, glossary definition of *Actinomyces*, 2001.

Alp, H., Yu, B.H., Grant, E.N., Rao, V., and Moy, J.N. "Cockroach allergy appears early in life in inner-city children with current wheezing." *Ann Allergy Asthma Immunol* 2001; 86(1): 51-54.

Alvarez, M.J., Olaguibel, J.M., Acero, S., Quirce, S., Garcia, B.E., Carillo, T., Cortes, C., and Tabar, A.I. "Indoor allergens and dwelling characteristics in two cities in Spain." *Journal of Investigational Allergology & Clinical Immunology* 1997; 7(6): 572-577.

Alvarez, M.J., Olaguibel, J.M., Acero, S., Garcia, B.E., Tabar, A.I., and Urbiola, E. "Effect of current exposure to Der p 1 on asthma symptoms, airway inflammation, and bronchial hyperresponsiveness in mite-allergic asthmatics." *Allergy* 2000; 55(2): 185-90.

American Academy of Pediatrics, Committee on Environmental Health. "Toxic effects of Indoor Molds". *Pediatrics* 1998; 101(4):712-714.

American Thoracic Society (Medical Section of the American Lung Association). "Supplement: American Thoracic Society Workshop Achieving Healthy Indoor Air, Report of the ALA/ATS Workshop, Santa Fe, NM Nov, 16-19, 1995" *Respiratory and Critical Care Medicine*, 1997, 156:533-564.

American Lung Association, American Medical Association, U.S. Consumer Product Safety Commission, and U.S. Environmental Protection Agency. "Indoor Air Pollution: An Introduction for Health Professionals". 1994. U.S. Government Printing Office 1994-523-217/81322. Available U.S. Environmental Protection Agency, (6607J) Washington, D.C. 20460.

Andersson, M.A., Nikulin, M., Köljalg, U., Andersson, M.C., Rainey, F., Reijula, K., Hintikka, E.-L., and Salkinoja-Salonen, M. "Bacteria, Molds and Toxins in Water-Damaged Building Materials". *Applied and Environmental Microbiology* 1997, 63(2):387-393.

Arai, Y., Obinata, K., Hisata, K., Tadokoro, R., Tawa, T., and Kinoshita, K. "Clinical significance of the serum surfactant protein D and KL-6 levels in patients with measles complicated by interstitial pneumonia." *European Journal of Pediatrics* 2001; 160(7):425-9.

Ayars, G.H. "Biological Agents and Indoor Air Pollution", 1997. Chapter 11 in *Indoor Air Pollution and Health*, by E.J. Bardana and A. Montanaro, editors. Michael Dekker Inc., 1997, ISBN 0-8247-4979-6.

Bardin, P.G., Fraenkel, D.J., Sanderson, G., van Schalkwyk, E.M., Holgate, S.T., and Johnston, S.L. "Peak expiratory flow changes during experimental rhinovirus infection." *Eur Respir J* 2000; 16(5): 980-985.

Barry, B.E. "Legionella". Chapter 48 in *Indoor Air Quality Handbook*, by Spengler, J.D., Samet, J.M., and McCarthy, J.F., eds., McGraw-Hill, 2001, ISBN 0-07-445549-4.

Bardana, E.J., and Montanaro, A., editors. "Indoor Air Pollution and Health". Michael Dekker Inc., 1997, ISBN 0-8247-4979-6.

Barker, J., Stevens, D., Bloomfield, S.F. "Spread and prevention of some common viral infections in community facilities and domestic homes." *Journal of Applied Microbiology* 2001; 91(1):7-21.

Bartlett, Karen. Personal communication, 2001.

Bates, D.V., and Sizto, R. "The Ontario Air Pollution Study: identification of the causative agent." *Environmental Health Perspectives*, 1989; 79:69-72.

Beach, J. R., Raven, J., Ingram, C., Bailey, M., Johns, D., Walters, E. H., and Abramson, M. "The effects on asthmatics of exposure to a conventional water-based and a volatile organic compound-free paint". *European Respiratory Journal* 1997; 10(3):563-566

Boadway, B.T., MacPhail, J., and Jacobson, C. "Ontario Medical Association position paper on health effects of ground-level ozone, acid aerosols and particulate matter". *Canadian Respiratory Journal* (Journal of the Canadian Thoracic Society) 1998; 5(5):367-384.

Bodner, C., Anderson, W.J., Reid, T.S., and Godden, D.J. "Childhood exposure to infection and risk of adult onset wheeze and atopy." *Thorax* 2000; 55(5): 383-387.

Boland, S., Baeza-Squiban, A., Fournier, T., Houcine, O., Gendron, M-C., Chévrier, M., Jouvenot, G., Coste, A., Aubier, M., and Marano, F. "Diesel exhaust particles are taken up by human airway epithelial cells in vitro and alter cytokine production". *AJP Lung Cellular and Molecular Physiology*, 1999; 276:L604-L613.

Bornehag, C.G., Blomquist, G., Gyntelberg, F., Järholm, B., Malmberg, P., Nordvall, L., Nielsen, A., Pershagen, G., and Sundell, J. "Dampness in Buildings and Health: Nordic Interdisciplinary Review of the Scientific Evidence on Associations between Exposure to "Dampness" in Buildings and Health Effects (NORDDAMP)". *Indoor Air* 2001, 11(2): 72-86.

Boulet, L.-P., Becker, A., Berube, D., Beveridge, R., Ernst, P. on behalf of the Canadian Asthma Consensus Group. "Summary of Recommendations from the Canadian Asthma Consensus Report". *CMAJ* 1999, 161 (11 suppl.): S1-S12.

Brauer, M. "Recreational Buildings". Chapter 67 in *Indoor Air Quality Handbook*, by Spengler, J.D., Samet, J.M., and McCarthy, J.F., eds., McGraw-Hill, 2001, ISBN 0-07-445549-4.

Burr, M.L., "Combustion Products." Chapter 29 in *Indoor Air Quality Handbook*, by Spengler, J.D., Samet, J.M., and McCarthy, J.F., eds., McGraw-Hill, 2001, ISBN 0-07-445549-4.

Burton, B.T. "Volatile Organic Compounds", 1997. Chapter 6 of *Indoor Air Pollution and Health*, edited by E. J. Bardana and A. Montanaro, Michael Dekker Inc., ISBN 0-8247-4979-6.

Busse, W.W., Gern, J.E., and Dick, E.C. "The role of respiratory viruses in asthma." *CIBA Clinical Symposia* 1997; 206(): 208-213.

Calder, R.A., Duclos, P., Wilder, M.H., Pryor, V.L., and Scheel, W.J. "Mycobacterium tuberculosis transmission in a health clinic." *Bull. Int. Union Tuberc. Lung Dis.* 1991; 66(2-3): 103-6.

Canada Mortgage and Housing Corporation. "The Effect of Improving the Home Environment on Asthma: A Pilot Study", 1999. Prepared by Buchan, Law, Parent Ltd., Gloucester, Ontario. Document PE-0362, available at <http://www.cmhc-schl.gc.ca> or 1-800-668-2642, CMHC, 700 Montreal Road, Ottawa K1A 0P7.

Canadian Lung Association. "Asthma" Web Site <http://www.lung.ca/asthma/asthma1.html>. 2001

Canadian Medical Association. "Summary of Recommendations from the Canadian Asthma Consensus Report, 1999". *Supplement to the Canadian Medical Association Journal (CMAJ)* 1999; 161 (11 Suppl).

Center for Disease Control (CDC). "Update: Pulmonary Hemorrhage/Hemosiderosis Among Infants – Cleveland, Ohio, 1993-1996." *MMWR Weekly* 2000; 49(09); 180-184.

Chandra, S., Beal, D., and Downing, A. "Allergy Resistant Housing – Principles and Practice." Presented at the "Environmental and Economic Balance: The 21st Century Outlook" conference, sponsored by the American Institute of Architects, The U.S. Green Building Council and the Department of Energy, Miami, Florida, November 6-9, 1997. Available from the Florida Solar Energy Center, Cocoa, Florida USA, <http://www.fsec.ucf.edu>.

Chan-Yeung, M., Becker, A., Lam, J., Dimich-Ward, H., Ferguson, A., Warren, P., Simons, E., Broder, I., and Manfreda, J. "House dust mite allergen levels in two cities in Canada: effects of season, humidity, city and home characteristics." *Clin Exp Allergy*, 1995; 25(3): 240-246.

Chen, Y., Tang, M., Krewski, D., and Dales, R. "Relationship Between Asthma Prevalence and Income Among Canadians". *JAMA* 2001; 286(9), Research Letter.

Ciuk, J., Volkmer, R.E., and Edwards, J.W. "Domestic nitrogen oxide exposure, urinary nitrate, and asthma prevalence in preschool children." *Arch Environ Health* 2001; 56(5): 433-438.

Committee of the Environmental and Occupational Health Assembly of the American Thoracic Society. "Health Effects of Outdoor Air Pollution". *Am. J. Respir. Crit. Care Med.*, 1996: 153(1):3-50.

Corbo, G.M., Forastiere, F., Agabiti, N., Dell'Orco, V., Pistelli, R., Aebischer, M.L., Valente, S., Perucci, C.A. "Effect of gas cooking on lung function in adolescents: modifying role of sex and immunoglobulin E." *Thorax*, 2001; 56(7): 536-540.

Cuyahoga County Board of Health, City of Cleveland Department of Public Health, and Case Western Reserve University. "A Report on the Proceedings of the Toxic Fungi Abatement Workshop: March 6 & 7, 1996". Cuyahoga County District Board of Health, 1375 Euclid Ave., 5th Floor, Cleveland, OH 44115-1882.

Dales, R.E., Burnett, R., and Zwanenburg, H. "Adverse Health Effects Among Adults Exposed to Home Dampness and Molds". *Am Rev. Respir. Dis.* 1991a; 143:505-509.

Dales R.E., Zwanenburg H., Burnett R., Franklin C.A. "Respiratory health effects of home dampness and molds among Canadian children." *Am J Epidemiol* 1991b; 134(2): 196-203.

Dales, R.E., Miller, D., and White, J. "Testing the association between residential fungus and health using ergosterol measures and cough recordings". *Mycopathologia*, 1999; 147(1):21-27.

Danuser, B., and Monn, C. "Endotoxins in the workplace and in the environment." *Schweiz Med Wochenschr* 1999; 129(12): 475-83.

Dean, J.H., Ward, E.C., Murray, M.J., Lauer, L.D., House, R.V. "Immunotoxicology of Polycyclic Aromatic Hydrocarbons". *NIH Immunotoxicology Workshop*, October 1983, pp. 259-273.

Dearborn, D.G. "Pulmonary haemorrhage in Infants and Children". *Current Opinion in Pediatrics* 1997; 9:219-224.

Dearborn, D.G., Yike, I., Sorenson, W.G., Miller, M.J., and Etzel, R.A. "Overview of Investigations into Pulmonary Haemorrhage among Infants in Cleveland, Ohio." *Environmental Health Perspectives* 1999; 107(supp.3): 495-499.

Delfino, R.J., Murphy-Moulton, A.M., Burnett, R.T., Brook, J.R., and Becklake, M.R. "Effects of air pollution on emergency room visits for respiratory illnesses in Montreal, Quebec." *American Journal of Respiratory and Critical Care Medicine* 1997; 155:568-576.

Devlin, R.B., Horstman, D.P., Gerrity, T.R., Becker, S., Madden, M.C., Biscardi, F., Hatch, G.E., and Koren, H.S. "Inflammatory response in humans exposed to 2.0 ppm nitrogen dioxide." *Inhal. Toxicology* 1999; 11(2): 89-109.

Douwes, J., van der Sluis, B., Doekes, G., van Leusden, F., Wijnand, L., van Strien, R., Verhoeff, A., and Brunekreef, B. "Fungal extracellular polysaccharides in house dust as a marker for exposure to fungi: relations with culturable fungi, reported home dampness, and respiratory symptoms." *J Allergy Clin Immunology* 1999; 103(3 Pt 1): 494-500.

Douwes, J., Zuidhof, A., Doekes, G., van der Zee, S.C., Wouters, I., Boezen, M.H., and Brunekreef, B. "(1→3)-β-D-Glucan and endotoxin in house dust and peak flow variability in children." *American Journal of Respiratory and Critical Care Medicine* 2000; 162(4 Pt 1):1348-54.

Dubus, J.C., Bosdure, E., Mates, M., and Mely, L. "Virus and respiratory allergy in children." *Allergy and Immunology (Paris)* 2001; 33(2): 78-81.

Elidemir, O., Colasurdo, G.N., Rossmann, S.n., and Fan, L.L. "Isolation of *Stachybotrys* From the Lung of a Child with Pulmonary Hemosiderosis". *Pediatrics* 1999; 104:964-966.

Etzel, R.A., Montana, E., Sorenson, W.G., Kullman, G.J., Allan, T.M., and Dearborn, D.G. "Acute Pulmonary Haemorrhage in Infants Associated with Exposure to *Stachybotrys Atra* and Other Fungi." *Arch Pediatr Adolesc Med* 1998; 152:757-762.

Fisk, W.J. "Estimates of Potential Nationwide Productivity and Health Benefits from Better Indoor Environments: An Update." Chapter 4 in *Indoor Air Quality Handbook*, by Spengler, J.D., Samet, J.M., and McCarthy, J.F., eds., McGraw-Hill, 2001, ISBN 0-07-445549-4.

Flannigan, B., McCabe, E.M., and McGarry, F. "Allergenic and Toxicogenic Micro-Organisms in Houses". *Journal of Applied Bacteriology Symposium Supplement* 1991; 70:61S-73S.

Fogarty, R., and Nelson, P.A. "Tracking Ultrafine Particles in Building Investigations". Chapter 50 in *Indoor Air Quality Handbook*, by Spengler, J.D., Samet, J.M., and McCarthy, J.F., eds., McGraw-Hill, 2001, ISBN 0-07-445549-4.

Fogelmark, B., Goto, H., Yuasa, k., Marchat, B., and Rylander, R. "Acute Pulmonary Toxicity of Inhaled β-1,3 glucan and Endotoxin." *Agents Actions* 1992, 35:50-56.

Frampton, M.W., Ghio, A.J., Samet, J.M., Carson, J.S., Carter, J.D., and Devlin, R.B. "Effects of aqueous extracts of PM₁₀ filters from the Utah Valley on human airway epithelial cells". *AJP Lung Cellular and Molecular Physiology* 1999; 277:L960-L967.

Garrett, M.H., Hooper, M.A., Hooper, B.M., and Abramson, M.J. "Respiratory Symptoms in Children and Indoor Exposure to Nitrogen Dioxide and Gas Stoves". *American Journal of Respiratory and Critical Care Medicine*, 1999; 158:891-895.

- Garrett, M.H., Hooper, M.A., Hooper, B.M., Rayment, P.R., and Abramson, M.J. "Increased risk of allergy in children due to formaldehyde exposure in homes." *Allergy* 1999;54(4): 330-7.
- Gehring, U., Douwes, J., Doekes, G., Koch, A., Bischof, W., Fahlbusch, B., Richter, K., Wichmann, H.E., and Heinrich, J. "Beta (1→3)-glucan in house dust of German homes: housing characteristics, occupant behaviour, and relations with endotoxins, allergens and molds." *Environmental Health Perspectives*, 2001; 109(2): 139-144.
- Gilliland, F.D., Li, Y.F., and Peters, J.M. "Effects of maternal smoking during pregnancy and environmental tobacco smoke on asthma and wheezing in children." *Am J Respir Crit Care Med* 2001; 163(2): 429-436.
- Goldberg, M.S., Burnett, R.T., Bailar, J.C. 3rd, Tamblyn, R., Ernst, P., Flegel, K., Brook, J., Bonvalot, Y., Singh, R., Valois, M.F., and Vincent, R. "Identification of persons with cardiorespiratory conditions who are at risk of dying from the acute effects of ambient air particles." *Environ Health Perspect* 2001; 109(Supp4): 487-494.
- Goldmann, D.A. "Transmission of viral respiratory infections in the home." *Pediatric Infectious Diseases Journal*, 2000; 19(10 Suppl): S97-102.
- Gereda, J.E., Klinnert, M.D., Price, M.R., Leung, D.Y., and Liu, A.H. "Metropolitan home living conditions associated with indoor endotoxin levels." *J Allergy Clin Immunol* 2001; 107(5): 790-796.
- Habbick, B.F., Pizzichini, M.M., Taylor, B., Rennie, D., Senthilselvan, A., and Sears, M.R. "Prevalence of Asthma, rhinitis and eczema among children in 2 Canadian cities: the International Study of Asthma and Allergies in Childhood. *CMAJ* 1999; 160(13): 1824-8.
- Hackshaw, A.K., Law, M.R., and Wald, N.J. "The accumulated evidence on lung cancer and environmental tobacco smoke. *Br. Med. J.* 1997; 315(7114): 980-988.
- Health and Welfare Canada. "Significant of Fungi in Indoor Air: Report of a Working Group". *Cdn. Journal of Public Health*, 1987; 78(2); S1-S14.
- Health Canada. "Exposure Guidelines for Residential Indoor Air Quality: A Report of the Federal-Provincial Advisory Committee on Environmental and Occupational Health". Revised July, 1989, Cat H46-2/90-156E, ISBN 0-662-17882-3 Minister of Supply and Services Canada 1995; available from Health Canada Publications/Communications, Ottawa K1A 0K9.
- Hirvonen, M-R., Nevalainen, A., Makkonen, N., Mönkkönen, J., and Savolainen, K. "Streptomyces spores from mouldy houses induce nitric oxide, TNF α and IL-6 secretion from RAW264.7 macrophage cell line without causing subsequent cell death." *Environmental Toxicology and Pharmacology*, 1997a, 3: 57-63
- Hirvonen, M-R., Nevalainen, A., Makkonen, N., Mönkkönen, J., and Savolainen, K. "Induced Production of Nitric Oxide, Tumor Necrosis Factor, and Interleukin-6 in RAW264.7 Macrophages by Streptomyces from Indoor Air of Mold Houses". *Archives of Environmental Health*, 1997b; 52:426-432.
- Hirvonen, M-R., Ruotsalainen, M., Roponen, M., Hyvärinen, A., Husman, T., Kosma, V-M., Komulainen, H., Savolainen, K., and Nevalainen, A. "Nitric Oxide and Proinflammatory Cytokines in Nasal Lavage Fluid Associated with Symptoms and Exposure to Moldy Building Microbes". *American Journal of Respiratory and Critical Care Medicine*, 1999, 160: 1943-1946.
- Holt, P.G. "Potential Role of Environmental Factors in the Etiology and Pathogenesis of Atopy: A Working Model". *Environmental Health Perspectives* 1999; 107(3):485-487.

- Howard, C., and Corsi, R.L. "Volatilization of chemicals from drinking water to indoor air: the role of residential washing machines." *J Air Waste Manag Assoc* 1998; 48(10): 907-914.
- Htut, T., Higenbottam, T.W., Gill, G.W., Darwin, R., Anderson, P.B., and Syed, N. "Eradication of house dust mite from homes of atopic asthmatic subjects: a double-blind trial." *Journal of Allergy and Clinical Immunology*, 2001; 107(1):55-60.
- Hunter, C.A., Grant, C., Flannigan, B., and Bravery, A.F. "Mould in Buildings: The Air Spora of Domestic Dwellings". *International Biodeterioration* 1988; 24:81-101.
- Husman, T., Koskinen, O., Hyvarinen, A., Reponen, T., Ruuskanen, J., and Nevalainen, A. "Respiratory Symptoms and Infections Among Residents in Dwellings with Moisture Problems or Mould Growth." *Proceedings of Indoor Air '93, Volume 1*.
- Huttunen, K., Jussila, Juha, Ruotsalainen, M., Iivanainen, E., Nevalainen, A., and Hirvonen, M-R. "Cytotoxicity and Inflammatory Responses Induced by Bacteria Isolated from Mouldy Houses: Comparison of Human and Mice Cells". *Proceedings of Healthy Buildings 2000*: 1:267-268.
- Ikeda, H., Iwai, K., Kawai, S., and Kobayashi, H. "Three cases of measles-associated interstitial pneumonia." *Nihon Kokyuki Gakkai Zasshi* 2000; 38(8): 615-21.
- Infante-Rivard, C. "Childhood asthma and indoor environmental risk factors." *Am J Epidemiol* 1993; 137(8): 834-844.
- Institute of Medicine. "Clearing the Air: Asthma and Indoor Air Exposures", 2000. Committee on the Assessment of Asthma and Indoor Air, Division of Health Promotion and Disease Prevention, Institute of Medicine (U.S.). Available National Academy Press, 1-800-624-6242, <http://www.nap.edu>.
- Jaakkola, J.J., Verkasalo, P.K., Jaakkola, N. "Plastic wall materials in the home and respiratory health in young children". *American Journal of Public Health*, 2000; 90(5):797-9.
- Jarvis, B.B., Sorenson, W.G., Hintikka, E-L., Nikulin, M., Zhou, Y., Jiang, J., Wang, S., Hinkley, S., Etzel, R., and Dearborn, D. "Study of Toxin Production by Isolates of *Stachybotrys chartarum* and *Memnoniella Echinata* Isolated during a Study of Pulmonary Hemosiderosis in Infants". *Applied and Environmental Microbiology* 1998; 64(10):3620-3625.
- Johanning, E., Morey, P.R., and Goldberg, M. "Remedial Techniques and Medical Surveillance Program for the Handling of Toxicogenic *Stachybotrys Atra*". *Proceedings of Indoor Air '93*, 1993; 4:311-316. Helsinki, Finland.
- Johnston, S.L., Pattermore, P.K., Sanderson, G., Smith, S., Lampe, F., Josephs, L., Symington, P., O'Toole, S., Myint, S.H., Tyrrell, D.A., and Holgate, S.T. "Community study of role of viral infections in exacerbations of asthma in 9-11 year old children." *British Medical Journal (International edition)* 1995; 310(6989):1225-1229.
- Kilpelainen, M., Terho, E.O., Helenius, H., and Koskenvuo, M. "Home dampness, current allergic diseases, and respiratory infections among young adults." *Thorax* 2001; 56(6): 462-7.
- Koskinen, A.M., Husman, T.M., Meklin, T.M., and Nevalainen, A.I. "The relationship between moisture or mould observations in houses and the state of health of their occupants". *European Respiratory Journal*, 1999; 14:1363-1367.

Lewis, Robert G. "Pesticides." Chapter 35 in *Indoor Air Quality Handbook*, by Spengler, J.D., Samet, J.M., and McCarthy, J.F., eds., McGraw-Hill, 2001, ISBN 0-07-445549-4.

Liccardi, G., Cazzola, M., D'Amato, M., and D'Amato, G. "Pets and cockroaches: two increasing causes of respiratory allergy in indoor environments. Characteristic of airways sensitization and prevention strategies." *Respiratory Medicine*, 2000; 94(11):1109-1118.

Litonjua, A.A., Carey, V.J., Burge, H.A., Weiss, S.T., and Gold, D.R. "Exposure to cockroach allergen in the home is associated with incident doctor-diagnosed asthma and recurrent wheezing." *Journal of Allergy and Clinical Immunology*, 2001; 107(1): 41-47.

Lynge, E., Anttila, A., and Hemminki, K. "Organic solvents and cancer." *Cancer Causes & Control* 1997; 8(3): 406-419.

Manuel, J. "A healthy home environment?" *Environmental Health Perspectives* 1999; 107(7): A352-357.

Mastrangelo, G., Fadda, E., and Marzia, V. "Polycyclic Aromatic Hydrocarbons and Cancer in Man" *Environmental Health Perspectives* 1996; 104(11): 1166-1170.

McBride, S.J., Ferro, A.R., Ott, W.R., Switzer, P., and Hildemann, L.M. "Investigations of the proximity effect for pollutants in the indoor environment." *J Expo Anal Environ Epidemiol* 1999; 9(6): 602-621.

McDonald, B., and Ouyang, M. "Air Cleaning — Particles". Chapter 9 in *Indoor Air Quality Handbook*, by Spengler, J.D., Samet, J.M., and McCarthy, J.F., eds., McGraw-Hill, 2001, ISBN 0-07-445549-4.

Miller, J.D., Laflamme, A.M., Sobol, Y., Lafontaine, P., and Greenhalgh, R. "Fungi and Fungal Products in Some Canadian Houses". *International Biodeterioration* 1988; 24:103-120.

Miller, J.D. "Fungi as Contaminants in Indoor Air". *Atmospheric Environment*, 1992; 26A(12):2163-2172.

Miller, J.D. and Day, J.H. "Indoor Mold Exposure: Epidemiology, Consequences and Immunotherapy". *Canadian Journal of Allergy & Clinical Immunology* 1997; 2(1):25-32.

Montaña, E., Etzel, R.A., Allan, T., Horgan, T., and Dearborn, D.G. Environmental "Risk Factors associated with Pediatric Idiopathic Pulmonary Haemorrhage and Hemosiderosis in a Cleveland Community". *Pediatrics* 1997; 99(1)

Montanaro, A. "Indoor Allergens: Description and Assessment of Health Risks", 1997. Chapter 9 of *Indoor Air Pollution and Health*, edited by E. J. Bardana and A. Montanaro, Michael Dekker Inc., ISBN 0-8247-4979-6.

Murphy, S. "Expert Panel Report 2: Guidelines for the Diagnosis and Management of Asthma." 97-4051, 1-86. National Institutes of Health, National Heart, Lung and Blood Institute, Washington, D.C., 1997.

Murtoniemi, T., Nevalainen, A., Suutari, M., Toivola, M., Konulainen, H., and Hirvonen, M-R. "Induction of Cytotoxicity and Production of Inflammatory Mediators in RAS264.7 Macrophages by Spores Grown on Six Different Plasterboards". *Inhalation Toxicology*, 2001; 13:233-247.

Myatt, T.A., and Milton, D.K., "Endotoxins", Chapter 42 in *Indoor Air Quality Handbook*, by Spengler, J.D., Samet, J.M., and McCarthy, J.F., eds., McGraw-Hill, 2001, ISBN 0-07-445549-4.

Nardell, E.A., Keagen, J., Cheney, S., and Etkind, S., "Airborne infection: theoretical limits of protection achievable by building ventilation." *American Review of Respiratory Diseases* 1991; 144: 302-6.

Nardell, E.A. "Disinfecting Air." Chapter 11 in *Indoor Air Quality Handbook*, by Spengler, J.D., Samet, J.M., and McCarthy, J.F., eds., McGraw-Hill, 2001, ISBN 0-07-445549-4.

New York City Department of Health. "Guidelines on Assessment and Remediation of *Stachybotrys Atra* in Indoor Environments". Proceedings of the International Conference on Fungi and Bacteria in Indoor Air Environments, October 6-7, 1994, Saratoga Springs, New York, ed. by E. Johanning and C. S. Yang. Eastern New York Occupational Health Program, 1996, , pp. 201-207.

New York City Department of Health. "Guidelines on Assessment and Remediation of Fungi in Indoor Environments." Available at NYC website <http://www.ci.nyc.ny.us/html/doh/html/epi/moldrpt1.html>. November 2000.

Nicolai, T., Illi, S., and von Mutius, E. "Effect of dampness at home in childhood on bronchial hyperreactivity in adolescence." *Thorax* 1998; 53(12): 1035-1040.

Nikulin, M., Reijula, K., Jarvis, B.B., and Hintikka, E.-L. "Experimental Lung Mycotoxicosis in Mice Induced by *Stachybotrys Atra*". *Int. J. Exp. Path.* 1996; 77:213-218.

Norback, D., Bjarsson, E., Janson, C., Palmgren, U., and Boman, G. "Current asthma and biochemical signs of inflammation in relation to building dampness in dwellings." *Int. J Tuberc Lung Dis* 1999; 3(5): 368-376.

Norback, D , Wieslander G , Nordstrom K , and Walinder R. "Asthma symptoms in relation to measured building dampness in upper concrete floor construction, and 2-ethyl-1-hexanol in indoor air". *Int J Tuberc Lung Dis*, 2000; 4(11): 1016-25.

Norback, D., Walinder, R., Wieslander, G., Smedje, G., Erwall, C., and Venge, P. "Indoor air pollutants in schools: nasal patency and biomarkers in nasal lavage". *Allergy*, 2000b; 55(2):163-70.

O'Malley, M. "Clinical evaluation of pesticide exposure and poisonings." *Lancet* 1997; 349(9059): 1161-1166.

Ontario Ministry of Health. "Report of an Expert Panel on Fungal Contamination Indoors: Convened on February 11-12, 1999". Ontario Ministry of Health, July 1999.

Ormstad, H. "Airborne dust particles in indoor environment and asthma". *Tidsskr Nor Laegeforen*, 2001; 121(11):1344-1350.

Ostro, B.D. "Estimating the risks of smoking, air pollution, and passive smoke on acute respiratory conditions." *Risk Anal* 1989; 9(2): 189-96.

Ostro, B.D., Lipsett, M.J., Mann, J.K., Wiener, M.B., and Selner, J. "Indoor air pollution and asthma: Results from a panel study." *American Journal of Respiratory and Critical Care Medicine* 1994; 149: 1400-1406.

Ozkaynak, H., Xue, J., Spengler, J., Wallace, L., Pellizzari, E., and Jenkins, P. "Personal exposure to airborne particles and metals: results from the Particle TEAM study in Riverside, California." *J Expo Anal Environ Epidemiol* 1996; 6(1): 57-58

Papadopolous, N.G., and Johnston, S.L. "Rhinoviruses as pathogens of the lower respiratory tract." *Can Respir J* 2000; 7(5): 409-414.

- Pappas, G.P., Herbert, R.J., Henderson, W., Koenig, J., Stover, B., and Barnhart, S. "The respiratory effects of volatile organic compounds." *International Journal of Occupational and Environmental Health* 2000; 6(1):1-8.
- Pasanen, A.-L., Nikulin, M., Tuomainen, M., Berg, S., Parikka, P. and Hintikka, E.-L. "Laboratory Experiments on Membrane Filter Sampling of Airborne Mycotoxins Produced by *Stachybotrys Atra Corda*". *Atmospheric Environment* 1993; 27A(1):9-13.
- Perzanowski, M.S., Ranmark, E., Nold, B., Lundback, B., and Platts-Mills, T.A. "Relevance of allergens from cats and dogs to asthma in the northernmost province of Sweden: schools as a major site of exposure." *Journal of Allergy and Clinical Immunology* 1999; 103(6):1018-1024.
- Pickering, C.A.C. and Newman Taylor, A.J. "Extrinsic allergic bronchioloalveolitis (hypersensitivity pneumonia)". In *Occupational Lung Disorders (Third Edition)*, edited by W. Raymond Parkes, Butterworth Heinemann. 1994.
- Pirhonen, I., Nevalainen, A., Husman, T., and Pekkanen, J. "Home dampness, moulds and their influence on respiratory infections and symptoms in adults in Finland." *Eur Respir J* 1996; 9: 2618-2622.
- Platts-Mills, T.A., Sporik, R.B., Chapman, M.D., and Heymann, P.W. "The role of domestic allergens [in asthma]". *CIBA Clinical Symposia* 1997; 206():173-85.
- Platts-Mills, T.A., Rakes, G., Heymann, P.W. "The relevance of allergen exposure to the development of asthma in childhood." *Journal of Allergy and Clinical Immunology*, 2000; 105(2Pt2): S503-S508.
- Platts-Mills, T.A., Vaughan, J.W., Blumenthal, K., Pollart Squillace, S., and Sporik, R.B. "Serum IgG and IgG4 antibodies to Fel d 1 among children exposed to 20 microg Fel d 1 at home: relevance of a nonallergic modified Th2 response." *Int. Arch. Allergy Immunol.* 2001; 124(1-3): 126-9.
- Poulos, L.M., O'Meara, T.J., Sporik, R., and Tovey, E.R. "Detection of Inhaled Der p 1." *Clin. Exp. Allergy* 1999; 29(9):1232-1238.
- Raabe, O. "Respiratory Exposure to Air Pollutants". Chapter 2 of *Air Pollutants and the Respiratory Tract*, 1999, edited by D. L. Swift and W. M. Foster. Lung Biology in Health and Disease, Volume 128, Marcel Dekker Inc., NY, ISBN 0-8247-9521-0.
- Reed, C.E., and Milton, D.K. "Endotoxin-stimulated innate immunity: A contributing factor for asthma." *J Allergy Clin Immunol* 2001; 108(2): 157-166.
- Riley, E.C., Murphy, G., and Riley, R.L. "Airborne Spread of Measles in a Suburban Elementary School." *American Journal of Epidemiology*, 1978; 107(5):421-432.
- Riley, R.L. "Indoor Airborne Infection". *Environment International*, 1982; 8:317-320.
- Rosenlund, M., and Bluhm, G. "Health effects resulting from nitrogen dioxide exposure in an indoor ice arena." *Archives of Environmental Health* 2000; 54(1):52-57.
- Rothman, N., Li, G.-L., Dosemeci, M., Bechtold, W.E., Marti, G.E., Wang, Y.-Z., Linet, M., Xi, L.-Q., Lu, W., and Smith, M.T. "Hematotoxicity Among Chinese Workers Heavily Exposed to Benzene." *American Journal of Industrial Medicine* 1996; 29(3): 236-246.

- Ruotsalainen, M., Hyvärinen, A., Nevalainen, A., and Savolainen, K.M. "Production of Reactive Oxygen Metabolites by Opsonized fungi and Bacteria Isolated from Indoor Air, and their Interactions with Soluble Stimil, fMLP or PMA". *Environmental Research* 1995; 69:122-131.
- Rylander, R., Persson, K., Goto, Hajime, Yuasa, K., and Tanaka, S. "Airborne Beta-1,3-Glucan May Be Related to Symptoms in Sick Buildings". *Indoor Environment* 1992; 1:263-267.
- Rylander, R. "Indoor Air-Related Effects and Airborne (1→3)-β-d-Glucan". *Environmental Health Perspectives* 1999; 107(Supp.3):501-503.
- Rylander, R., and Etzel, R. "Introduction and Summary: Workshop on Children's Health and Indoor Mold Exposure". *Environmental Health Perspectives* 1999; 107(3):465-468.
- Rylander, R., and Lin, R.H. "(1→3)-β-D-glucan – relationship to indoor air-related symptoms, allergy and asthma." *Toxicology* 2000; 152(1-3):47-52
- SafetyLine Institute. "Airborne Particulate Matter". From a SafetyLine Institute Toxicology Lecture Series. Website http://www.safetyline.wa.gov.au/institute/level2/course16/lecture46/146_02.asp. 1998.
- Salome, C.M., Marks, G.B., Savides, P., Xuan, W., and Woolcock, A.J. "The effect of insecticide aerosols on lung function, airway responsiveness and symptoms in asthmatic subjects." *Eur Respir J* 2000; 16(1): 38-43.
- Samet, J.M., and Cohen, A.J. "Air Pollution and Lung Cancer", 1999, Chapter 7 of *Air Pollutants and the Respiratory Tract*, 1999, edited by D. L. Swift and W. M. Foster. Lung Biology in Health and Disease, Volume 128, Marcel Dekker Inc., NY, ISBN 0-8247-9521-0.
- Samet, J.M. "Radon". Chapter 40 in *Indoor Air Quality Handbook*, by Spengler, J.D., Samet, J.M., and McCarthy, J.F., eds., McGraw-Hill, 2001, ISBN 0-07-445549-4.
- Samet, J.M., and Wang, S.S. "Environmental Tobacco Smoke". Chapter 30 in *Indoor Air Quality Handbook*, by Spengler, J.D., Samet, J.M., and McCarthy, J.F., eds., McGraw-Hill, 2001, ISBN 0-07-445549-4.
- Sandler, D.P., Everson, R.B., Wilcox, A.J., and Browder, J.P. "Cancer Risk in Adulthood from Early Life Exposure to Parents' Smoking." *American Journal of Public Health* 1985; 75(5):487-492.
- Savilahti, R., Uitti, J., Laippala, P., Husman, T., and Roto, P. "Respiratory morbidity among children following renovation of a water-damaged school." *Archives of Environmental Health* 2000; 55(6): 405-410.
- Schwartz, J. "Air pollution and daily mortality." *Environmental Research* 1994; 64:36-52.
- Schwartz, J. "Air pollution and hospital admissions for respiratory disease". *Epidemiology* 1996; 7:20-28.
- Scientific Committee on Tobacco and Health, HSMO. "Report of the Scientific Committee on Tobacco and Health." 011322124x. The Stationery Office, 1998.
- Shapiro, G.G., Wighton, T.G., Chinn, T., Zuckerman, J., Eliassen, A.H., Picciano, J.F., and Platts-Mills, T.A. "House dust mite avoidance for children with asthma in homes of low-income families." *Journal of Allergy and Clinical Immunology* 1999; 103(6): 1069-1074.
- Sherrill, D., Stein, R., Kurzius-Spencer, M., and Martinez, F. "On early sensitization to allergens and development of respiratory symptoms." *Clin Exp Allergy* 1999; 29(7): 905-911.

Shusterman, D.J., Murphy, M.A., and Balmes, J.R. "Subjects with seasonal allergic rhinitis and nonrhinitic subjects react differentially to nasal provocation with chlorine gas." *J Allergy Clin Immunol* 1998; 101(6 Pt 1): 732-740.

Small, Bruce M. "Evidence and Unknowns: The Health Effects of *Stachybotrys chartarum*", paper prepared for Pollution Probe, 2000. Pollution Probe, 625 Church Street, Suite 402, Toronto, Ontario M4Y 2G1, Tel: 416-926-1907.

Smith, B.J., Nitschke, M., Pilotto, L.S., Ruffin, R.E., Pisaniello, D.L., Willson, K.J. "Health effects of daily nitrogen dioxide exposure in people with asthma." *European Respiratory Journal*, 2000; 16(5): 879-85.

Stjernfeldt, M., Berglund, K., and Lindsten, J. "Maternal Smoking During Pregnancy and Risk of Childhood Cancer". *Lancet* 1986; 1(8494):1350-1352.

Strachan, D.P., and Sanders, C.H. "Damp Housing and Childhood Asthma; Respiratory Effects of indoor Air Temperature and Relative Humidity". *Journal of Epidemiology and Community Health* 1989; 43:7-14.

Summerbell, R. "Health Effect of *Stachybotrys*, Known and Inferred". Ontario Ministry of Health, May 1998.

Swift, D.L. and Foster, W.M. "Air Pollutants and the Respiratory Tract", 1999. Lung Biology in Health and Disease, Volume 128, Marcel Dekker Inc., NY, ISBN 0-8247-9521-0.

Tarlo, S.M., Broder, I., Corey, P., Chan-Yeung, M., Ferguson, A., Becker, A., Warren, P., Simons, F.E., Sherlock, C., Okada, M., and Manfreda, J. "A case-control study of the role of cold symptoms and other historical triggering factors in asthma exacerbations." *Canadian Respiratory Journal* 2000; 7(1): 42-48.

Tarlo, S.M., Broder, I., Corey, P., Chan-Yeung, M., Ferguson, A., Becker, A., Rogers, C., Okada, M., and Manfreda, J. "The role of symptomatic colds in asthma exacerbations: Influence of outdoor allergens and air pollutants." *J Allergy Clin Immunol* 2001; 108(1): 52-58.

Taskinen, T., Meklin, T., Nousiainen, M., Husman, T., Nevalainen, A., and Korppi, M. "Moisture and mould problems in schools and respiratory manifestations in schoolchildren: clinical and skin test findings." *Acta Paediatr* 1997; 86:1181-7.

Thurston, G. D., Ito, K., Hayes, C. G. , and Bates, D. V. "Respiratory Hospital Admissions and Summertime Haze Air Pollution in Toronto, Ontario: Consideration of the Role of Acid Aerosols". *Environmental Research*, 1994; 65(2):271ff.

TSI Incorporated. "Health-Based Particle-Size-Selective Sampling — Application Note ITI-050" Website: http://www.tsi.com/partsamp/appnote/iti_050.htm. 2002.

Tuomainen, M., Pasanen, A-L., Tuomainen, A., Liesivuori, J., and Juvonen, P. "Usefulness of the Finnish classification of indoor climate, construction and finishing materials: comparison of indoor climate between two new blocks of flats in Finland". *Atmospheric Environment* 2001, 35: 305-313.

Underhill, D., "Removal of Gases and Vapors". Chapter 10 in *Indoor Air Quality Handbook*, by Spengler, J.D., Samet, J.M., and McCarthy, J.F., eds., McGraw-Hill, 2001, ISBN 0-07-445549-4.

U.S. Environmental Protection Agency. "Air Quality Criteria for Particulate Matter and Sulfur Oxides", 1982. EPA-600/8-82-029aF-cF.3v. Research Triangle Park, NC.

Vanderbilt University Medical Center. "Pulmonary Hemosiderosis", 1998.
URL: <http://www.mc.vanderbilt.edu/peds/pidl/pulmon/index.htm> .

Verhoeff, A.P., and Burge, H.A. "Health Risk Assessment of Fungi in Home Environments". *Annals of Allergy, Asthma & Immunology* 1997; 78(6):544-556.

Wadden, R.A., and Scheff, P.A. "Indoor Air Pollution: Characterization, Prediction and Control". John Wiley & Sons Inc., 1983, ISBN 0-471-87673-9.

Waegemaekers, M., van Wageningen, N., Brunekreef, B., and Boleij, J.S.M. "Respiratory Symptoms in Damp Homes". *Allergy* 1989; 44:192-198.

Walinder, R., Norback, D., Wessen, B., and Venge, P. "Nasal lavage biomarkers: effect of water damage and microbial growth in an office building." *Archives of Environmental Health* 2001; 56(1): 30-36.

Wallace, L.A. "Assessing Human Exposure to Volatile Organic Compounds". Chapter 33 in *Indoor Air Quality Handbook*, by Spengler, J.D., Samet, J.M., and McCarthy, J.F., eds., McGraw-Hill, 2001, ISBN 0-07-445549-4.

Weiss, S.T., O'Connor, G.T., Demolles, D., Platts-Mills, T., and Sparrow, D. "Indoor allergens and longitudinal FEV1 decline in older adults: The Normative Aging Study." *Journal of Allergy and Clinical Immunology* 1998; 101(6-1): 720-725.

Wever-Hess, J., Kouwenberg, J.M., Duiverman, E.J., Hermans, J., and Wever, A.M. "Risk factors for exacerbations and hospital admissions in asthma of early childhood." *Pediatr Pulmonol* 2000; 29(4): 250-256.

Whitmore, R.W., Immerman, F.W., Camann, D.E., Bond, A.E., Lewis, R.G., and Schaum, J.L. "Nonoccupational exposure to pesticides for residents of two U.S. cities." *Arch. Environ. Contam. Toxicol.* 1994; 123: 1-69.

Wilkins, C.K., Larsen, S.T., Hammer, M., Poulsen, O.M., Wolkoff, P., and Nielsen, G.D. "Respiratory Effects in Mice Exposed to Airborne Emissions from *Stachybotrys chartarum* and Implications for Risk Assessment." *Pharmacology & Toxicology* 1998; 83:112-119.

Wittman, A.M., Mulder, M., Aalberse, R.C., Jansen, H.M., van der Zee, J.S. "Bronchial allergen challenge in subjects with low levels of allergic sensitization to indoor allergens." *Allergy* 1999; 54(4):366-374.

Yang, C.Y., Chiu, J.F., Cheng, M.F., and Lin, M.C. "Effects of indoor environmental factors on respiratory health of children in a subtropical climate." *Environ Res* 1997; 75(1): 49-55.

Yin, S.N., Hayes, R.B., Linet, M.S., Li, G.L., Dosemeci, M., Travis, L.B., Chow, W.H., and Wacholder, S. "An expanded cohort study of cancer among benzene-exposed workers in China". *Environmental Health Perspectives* 1996; 104(6):1339-1341.

Yoon, S.S., MacDonald, S.C., and Parrish, R.G. "Deaths from unintentional carbon monoxide poisoning and potential for prevention with carbon monoxide detectors." *JAMA* 1998; 279(9): 685-7.

Zacharasiewicz, A., Zidek, T., Haldinger, G., Waldhor, T., Suess, G., and Vutuv, C. "Indoor factors and their association to respiratory symptoms suggestive of asthma in Austrian children aged 6-9 years." *Wien Klin Wochenschr* 1999; 111(21): 882-6.

Zemp, E., Elsasser, S., Schindler, C., Künzli, N., Perruchoud, A.P., Domenighetto, G., Medici, T., Ackermann-Liebrich, U., Leuenberger, P., Monn, C., Bolognini, G., Bongard, J-P., Brändli, O., Karrer, W., Keller, R., Schöni,

M.H., Tschopp, J-M., Villiger, B., Zellweger, J-P., and the Sapaldi Team. "Long-Term Ambient Air Pollution and Respiratory Symptoms in Adults (SAPALDIA Study)." *American Journal of Respiratory and Critical Care Medicine*, 1999; 159:1257-1266.

Zock, J.P., Kogevinas, M., Sunyer, J., Almar, E., Muniozguren, N., Payo, F., Sanchez, J.L, and Anta, J.M. "Asthma risk, cleaning activities and use of specific cleaning products among Spanish indoor cleaners". *Scandinavian Journal of Work and Environmental Health* 2001; 27(1):76-81.

APPENDIX 1: Brief Background on Specific Respiratory Diseases

The following sections provide further information on some of the specific respiratory disorders referenced in the preceding text.

Asthma

One common international definition of asthma states: Asthma is a chronic inflammatory disorder of the airways in which many cells and cellular elements play a role, in particular, mast cells, eosinophils, T lymphocytes, macrophages, neutrophils, and epithelial cells. In susceptible individuals, this inflammation causes recurrent episodes of wheezing, breathlessness, chest tightness, and coughing, particularly at night or in the early morning. These episodes are usually associated with widespread but variable airflow obstruction that is often reversible either spontaneously or with treatment. The inflammation also causes an associated increase in the existing bronchial hyperresponsiveness to a variety of stimuli. (Murphy, 1997) (Institute of Medicine, 2000)

The Canadian Medical Association describes asthma as follows: Asthma is characterized by paroxysmal or persistent symptoms such as dyspnea, chest tightness, wheezing, sputum production and cough, associated with reversible airflow obstruction and a variable degree of hyperresponsiveness of airways to endogenous or exogenous stimuli. (Hyperresponsiveness refers to the abnormally large response of the airways to the inhalation of minor irritants such as cold air.) Inflammation and its resultant effects on airway structure are considered to be the main mechanisms leading to the development and maintenance of asthma. (Canadian Medical Association, 1999)

Asthma is one of the most common chronic diseases in Canada, affecting 6-8% of people 12 years of age or older. (Chen *et al.*, 2001) According to the Lung Association, 7-10% of the pediatric population have been diagnosed as asthmatic. (Canadian Lung Association, 2001). Prevalence rates vary for different age groups and in different locations in Canada. For example, the lifetime prevalence of asthma was 17.2% in Hamilton and 11.2% in Saskatoon for children 6 and 7 years old, and 19.2% and 12.2% respectively for children 13 and 14 years old. (Habbick *et al.*, 1999)

Respiratory Irritation

Respiratory irritation response to indoor pollutants can be extremely complex. It can also vary according to individual susceptibility, the nature and concentration of the irritant, the duration of exposure, the route of inhalation, and other factors. The following more general discussion of irritants will provide background for discussion of other irritants in later sections.

Respiratory irritants comprise gases, vapours, and inhalable particles of varied inorganic and organic chemical classes that can cause discomfort upon inhalation and/or alter ventilation or breathing mechanics. The impact of an inhaled irritant can be immediate or delayed, and can affect the upper or lower respiratory tract.

Irritants act directly on neuronal receptors or nerve termini within exposed mucous membranes of the respiratory tract. High concentrations of irritants can also be cytotoxic, causing tissue damage directly or even secondarily as a result of inflammation, which has its own arsenal of endogenous irritants. This secondary inflammatory response can amplify or otherwise complicate the initial irritant response. (Swift and Foster, 1999)

Irritants can be divided into upper tract irritants (generally water-soluble chemicals which readily dissolve into the aqueous mucous fluids of the upper airways and typically elicit sensory discomfort) and lower tract irritants (which are usually less-water-soluble chemicals which deposit and evoke their primary stimulus in the lower respiratory tract).

Irritants can cause contraction of airway smooth muscles, submucosal edema, and mucus secretion. These cause bronchoconstriction, which increases airway resistance and makes it more difficult to breathe. Bronchoconstriction can alter both the entry and distribution of air in the lungs. At low concentrations, sensory irritants may go unperceived or may be sensed nonspecifically as discomfort. Continued exposure usually results in quantifiable alterations in lung mechanics. (Swift and Foster, 1999)

Stimulation of the nose, mouth and nasopharynx/larynx can also elicit a broad spectrum of reflex responses, including bronchomotor response (constriction or dilation) and cough. Irritant nasal stimulation can reflexively increase total airway resistance via laryngeal constriction, even while eliciting bronchodilation of the lower conducting airways. Chemical irritation beyond the nose can result in laryngeal narrowing bronchoconstriction with or without cough. (Swift and Foster, 1999)

Hypersensitivity Pneumonitis (Extrinsic Allergic Alveolitis)

Hypersensitivity pneumonitis or extrinsic allergic alveolitis is an immunological respiratory syndrome that results from the inhalation of and sensitization to antigens from various sources, including bacteria such as Actinomycetes, other organisms such as the amoeba *Naegleria* and *Acanthamoeba*, and proteins from animal sources (e.g. rat urine). In the acute form, typical symptoms are respiratory (e.g. cough, dyspnea), with associated systemic manifestations (e.g. fever, chills, myalgias and malaise). Following multiple exposures leading to sensitization, acute symptoms usually occur four to six hours after subsequent inhalation. In individuals with chronic or recurrent exposure to pneumonitis-inducing antigens, the pulmonary disease may progress insidiously, with increasing cough and dyspnea. Chronic disease may then lead to irreversible interstitial fibrotic lung disease. (Ayars, 1997)

It is important to realize that hypersensitivity pneumonitis (extrinsic allergic alveolitis) is multifactorial and is related to organic dust which can be bacterial, fungal or antigenic in nature). This is well illustrated in the following table: (Pickering and Taylor, 1994)

Alias	Nature of responsible aerosol	Nature of antigen
Farmers' Lung	Mouldy hay, straw or grain	<i>F. rectivirgula</i> , <i>T. vulgaris</i> , <i>T. thalophilus</i>
Bird Fancier's Lung	Bloom, droppings	Avian proteins
Bagassosis	Mouldy sugar cane	<i>T. sacchari</i>
Mushroom workers' lung	Compost dust	Thermophilic actinomycetes, mushroom spores
Malt workers' lung	Mouldy barley	<i>Aspergillus clavatus</i>
Suberosis	Mouldy corkbark dust	<i>Penicillium frequentans</i>
Maple bark strippers' lung	Mouldy bark dust	<i>Cryptostroma corticale</i>
Wood pulp workers' disease	Mouldy bark dust	<i>Alternaria sp.</i>
Air-conditioner disease	Dust or mist	<i>F. rectivirgula</i> , <i>A. pullans</i> , <i>T. vurlagis</i> , <i>Cephalosporium sp.</i>
Humidifier fever	Contaminated water	Endotoxin
Sewage sludge disease	Dust of heat-treated sludge	Gram-negative bacteria
Sauna takers' disease	Contaminated steam	<i>Aureobasidium pullans</i>
Sequoiosis	Mouldy sawdust – redwood	<i>Aureobasidium pullans</i>
Cheese washers' lung	Mould dust	<i>Penicillium casei</i>
Dry rot lung	Mould dust	<i>Merulius lacrymans</i>
Wheat weevil lung	Mouldy grain and flour dust	<i>Sitophilus granaries</i>
Animal handlers' lung	Dust or dander, hair particles, and dried urine of rats	Serum and urine proteins
Fish meal workers' lung	Fish meal dust	Fish proteins
Winegrowers' lung	Mould dust	<i>Botrytis cinerea</i>
Potato riddlers' lung	Straw dust	<i>F. rectivirgula</i>
Fertilizer workers' lung	Air-borne bacteria	<i>Streptomyces albus</i>

Woodmens' disease	Mouldy bark dust	<i>Penicillium sp.</i>
-------------------	------------------	------------------------

Ideopathic Pulmonary Haemorrhage and Pulmonary Hemosiderosis

Pulmonary hemosiderosis is characterized by accumulation of iron in the form of hemosiderin in the alveolar macrophages. Pulmonary hemosiderosis may occur as a primary phenomenon, most commonly in children, or it may complicate another underlying illness such as cardiac disease or collagen vascular disease. The majority of patients with primary pulmonary hemosiderosis have the isolated or idiopathic form. This disorder occurs most frequently in the first decade of life. Cases are distributed equally among males and females. Clinically, the process is characterized by the acute or insidious onset of pulmonary symptoms including cough, hemoptysis, wheezing, cyanosis, and dyspnea. Hematemesis may occur as a result of swallowed pulmonary blood. Other common findings include pallor from anemia, poor weight gain, and fatigue. The long-term course is usually characterized by intermittent episodes of pulmonary haemorrhage with associated fever, tachycardia, and tachypnea. (Vanderbilt University Medical Center, 1998)