INDOOR AIR POLLUTION

AND

HOUSING TECHNOLOGY

SUMMARY REPORT

INDOOR AIR POLLUTION
AND
HOUSING TECHNOLOGY

PREPARED FOR

THE RESEARCH DIVISION
POLICY DEVELOPMENT AND RESEARCH SECTOR
CANADA MORTGAGE AND HOUSING CORPORATION

BY

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Canada Mortgage and Housing Corporation, the Federal Government's housing agency, is responsible for administering the National Housing Act.

This legislation is designed to aid in the improvement of housing and living conditions in Canada. As a result, the Corporation has interests in all aspects of housing and urban growth and development.

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This publication is one of the many items of information published by CMHC with the assistance of federal funds.

SUMMARY REPORT

INDOOR AIR POLLUTION AND HOUSING TECHNOLOGY

This report summarizes a study conducted by Bruce M. Small and Associates Limited for Canada Mortgage and Housing Corporation under Part V of the National Housing Act. The analysis and interpretations are those of the consultant and do not necessarily reflect the views of Canada Mortgage and Housing Corporation or those divisions of the Corporation that assisted in the study and its publication.

This Summary Report and the study from which it is extracted, Indoor Air Pollution and Housing Technology are available from:

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OBJECTIVES OF "INDOOR AIR POLLUTION AND HOUSING TECHNOLOGY"

Indoor Air Pollution and Housing Technology addresses the lack of readily available information on indoor air quality especially as this relates to Canadian building practices, habits and climate. A review of the interactions between building technology, indoor air pollution and associated health effects is a useful reference to those with interest in this field.

The report is primarily a research-oriented review. As such, it indicates the extent to which building practices may need to be changed to achieve a clean indoor environment but not the cost effectiveness of such actions.

Until recently, interest in air pollution and its effects on health has focused on the outdoor environment. The emphasis is now shifting to the indoors where Canadians spend most of their time. The increased sophistication of measurement technologies and widening medical research have indicated that indoor air pollution could also present a health problem.

Rising energy prices have caused Canadians to "tighten-up" existing homes. New housing is being built with reduced air infiltration rates. Reduced ventilation allows indoor pollutants to build up, often to dangerous levels.

This phenomenon is intensified by the widespread use of new materials in home construction. Many of these products--insulation, composite materials, glues, sealants and furnishing--give off small quantities of chemicals used in their manufacture. The total of all these materials "gassing-off" in a closed environment presents an air quality problem.

The objectives of the study were threefold:

INDOOR AIR POLLUTION

To review literature and contact appropriate researchers to determine whether or not there are significant indoor air pollution problems in Canadian residences. Further, if these problems are found, to examine the nature of these problems, their causes and their possible solutions.

LOW POLLUTION DESIGN AND CONSTRUCTION

To review the literature and contact appropriate researchers in the building and health fields to determine materials, systems and methods of construction that would achieve low indoor air pollution levels which are compatible with energy efficiency. Further, to document design and construction methods used in the author's low pollution research facility.

CHEMICAL SUSCEPTIBILITY

To address problems and report on the extent and nature of chemical susceptibility among the Canadian population.

LITERATURE REVIEW

Indoor Air Pollution and Housing Technology summarizes and interprets key findings reported in the review of available literature. The six major observations follow.

1) **Many materials and conditions which contribute significantly to indoor air pollution are known to be present in Canadian homes.**

The number of Canadian homes in question is unknown. Research and measurements have been performed mainly in the U.S. and Europe. However, many construction materials commonly used in Canadian homes have been tested in the U.S.

Typically, dwellings contain many air contaminants at relatively low concentrations. These low levels can pose a problem for high risk groups; the long-term risk to the general population is unknown.

Pollutants posing the greatest hazard, and known to exceed existing criteria in some Canadian homes, include carbon monoxide, nitrogen dioxide, formaldehyde and radon gas.

Poorly ventialted or badly maintained combustion equipment, the trend to greater use of synthetic materials and reduced ventilation to conserve energy are cited as major contributors.

2) **Some people are more susceptible to air pollution than others, and individual susceptibility varies over time.**

It is known that air pollution can cause or aggravate disease in select populations which include the very young and old, smokers, and persons with

respiratory, cardiovascular or allergenic diseases and nutritional deficiencies.

Risk varies with the pollutant, the intensity of exposure, time, dietary habits, stress and presence of multiple pollutants. Persons included in these risk categories are estimated by the report to total more than one-third of the Canadian population.

3) Smoking remains a major source of indoor pollution.

Smoking is a major source of indoor air pollution and burning tobacco is too efficient a pollution source to ventilate properly.

Acceptance of smoking has made it difficult to justify concern over health effects from other pollution sources. As action is taken on chemicals such as formaldehyde, tobacco stands out more prominently as a problem that can no longer be accepted. People appear to be aware of the significant adverse health effects both on the smoker and on close companions breathing sidestream pollutants from smoking.

As smoking is likely to continue for years to come, better ventilation, as close to the smoker as possible, is an urgent requirement. The idea of adapting housing to limited tobacco use with spot ventilation of small smoking areas has been suggested.

4) Some energy conservation measures aggravate indoor pollution problems.

Energy conservation measures, reduction of ventilation, use of volatile materials and poorly installed or maintained combustion equipment are in part responsible for the apparent increase of indoor air pollution.

Available literature indicates that some researchers are developing energy conservation measures which recognize indoor air quality as a priority and do not aggravate indoor pollution.

To an extent, the cost of providing clean indoor air can be measured most directly by the energy cost of ventilation. Careful selection of materials to minimize pollution and the use of heat exchangers to cut energy losses are promising developments.

5) The full health, social and economic costs of indoor air pollution have yet to be determined.

The gaps in knowledge about the effects of indoor air pollution are extensive and result in a serious inability to prove or disprove claims. There are no adequate residential standards and even the basis on which industrial standards have been developed has been called into question.

The study poses numerous questions for which no reasonable answers can be found in existing literature. It is clear that little is known about the incidence of indoor pollution, who is exposed, who is adversely affected and what this means in social and economic terms. More subtle questions as to the long-term effects of multiple low-level exposures and the means of treatment and rehabilitation are also unanswered.

6) Acceptable levels of effects on health have not been defined.

With few exceptions the literature fails to discuss the levels of health effects that would be acceptable to society. Risk analysis could determine the level of negative impacts we would have to exchange for affordable, energy efficient housing.

A comprehensive approach to design and construction practice that promotes good health is almost totally absent in the literature and in design and construction practice.

STUDY ELEMENTS

A. Indoor Air Pollutants

The report enumerates the major categories of indoor air pollutants and provides, for each, a physical description of the substance, major sources, typical ranges of concentration, existing standards for human exposure, incidence, known health effects and a closing discussion.

The findings vary a great deal. Some pollutants such as carbon monoxide or cigarette smoke have been the subject of numerous studies, while others have received little attention.

Research has been performed mainly in the United States and Europe. The author concludes that many questions remain unanswered especially those which deal with incidence, long term health risks and the development of residential exposure standards.

The pollutants examined in the report include:

Carbon Monoxide	House Dust
Radon	Fungi (Mould)
Nitrogen Oxides	Bacteria/Viruses
Sulphur Dioxide	Aerosols
Ozone	Other Particulates
Asbestos	Pesticides
Tobacco Smoke	Ammonia
Formaldehyde	Chlorine
Carbon Dioxide	Organic Vapours

Pollutant	Descriptive Summary
Carbon Monoxide	Major sources are gas stoves, fossil fuel furnaces and heaters. Exposure is widespread and often at levels above outdoor standards. Faulty furnaces have given rise to fatal carbon monoxide concentrations.
Radon	Radon and radon decay products are present in most homes and may present a measurable cancer risk from radiation. Concentrations are greater in energy-efficient homes with reduced ventilation.
Nitrogen Oxides	Tobacco smoking and indoor combustion appliances are the major sources, often at levels exceeding outdoor ambient standards. Increased incidence of illness has been correlated with elevated NO2 and other pollutant levels in homes with gas stoves.
Sulphur Dioxide	Indoor concentrations often lower than those outside due to adsoprtion on building surfaces. Fossil fuel combustion is primary indoor source.
Ozone	Improperly maintained electrostatic air filters can produce ozone at levels above outdoor ambient standards. Persons already hyperreactive are at greatest risk.
Asbestos	Potential sources include many products no longer produced but still present in many homes. Fibers are carcinogenic.
Tobacco Smoke	Tobacco smoking is the major source of indoor respirable suspended particulates, producing concentrations well in excess of outdoor ambient standards. Contains known and potent carcinogens. Detrimental effects on the health of smokers and nonsmokers have been well documented.
Formaldehyde	Major sources including building materials and furnishings. Adverse health effects have been documented, even at levels below new indoor standards. Exposure can lead in some cases to widespread chemical susceptibility. Suspected carcinogen.

Pollutant	Descriptive Summary
Carbon Dioxide	Indoor concentrations are often very much greater than outdoor concentrations. Unvented kerosene heaters can produce concentrations well in excess of occupational standards. Long-term health effects from these levels are not well researched but are a cause for concern.
House Dust	House dust contains a wide variety of compounds that can be allergenic and therefore may adversely affect the health of a significant proportion of the population. A reasonable degree of avoidance for affected persons is feasible.
Fungi (Mould)	Mould is universally present in homes but may grow significantly if there are sources of dampness. Moulds contain potent allergenic compounds and can adversely affect health. They can be controlled with proper construction methods and environmental conditions.
Bacteria/Viruses	Bacteria may grow in warm standing water such as is found in some humidifiers. Health effects are potentially serious, but the incidence is not known and may be small. Transmission of infection by bacteria and virus increases with reduced ventilation.
Aerosols	Many consumer aerosol products yield high pollutant concentrations that could present serious health hazards. Persons with cardiovascular or pulmonary impairment are at greater risk.
Other Particulates	Various household materials and activities in addition to smoking produce suspended particulates. Some particulates can cause irritation and lung disease. More research is needed particularly concerning possible carcinogens.
Pesticides	Pesticides are widely used indoors and measurable concentrations have been found in human blood and tissue. Numerous incidents of illness have been reported and pesticides are suspected to be potent sensitizers which can lead to a more widespread chemical susceptibility.

Pollutant	Descriptive Summary
Ammonia	Ammonia is often present in indoor air in small quantities and is known to irritate those susceptible. Little data on incidence or health effects at low levels is available.
Chlorine	Chlorine compounds are present in the home particularly in laundry preparations and in municipal water. Chemically susceptible individuals are known to be adversely affected but no data is available on indoor concentrations or long term health effects.
Organic Vapours	Indoor air often contains complex mixes of organic vapours, each at low levels but in combination at levels exceeding outdoor and other standards. Little in known of the short and long-term health effects of many of the organic compounds mentioned, at the low levels of exposure that occur. Many compounds present have detrimental effects at high concentrations and are known to affect hypersusceptible persons at levels commonly found in homes.

B. The People Affected

The report observes that indoor air pollution appears to adversely affect people in a number of ways. These include;

- o direct toxic and irritant effects
- o increased susceptibility to developing disease from other causes
- o aggravation of existing disease
- o sensitization to the same and other environmental agents
- o addition to our total "stress" load

Studies indicate that high level exposures of many pollutants put anyone in the general population at risk. At least a small proportion of the population may be at risk of developing effects other than direct toxic or irritant effects when exposed to low levels of a wide array of pollutants.

Specific high risk groups include the very young, the very old, pregnant women, people with respiratory ailments or cardiovascular disease, people with certain genetic backgrounds, dietary habits or nutritional deficiencies, people who consume large amounts of alcohol or drugs, people who smoke and various others.

Persons who have become sensitized to low-level exposures of various pollutants represent a special risk category. In some cases a mild sensitivity to one chemical gradually "spreads" to other chemicals. For the chemically susceptible person, household chemicals apparently tolerated by most of the population may provoke a wide variety of symptoms.

U.S. studies have indicated a total of 25 to 35 million people who would experience higher than normal risk in exposure to a number of pollutants because of chronic respiratory disease and heart disease alone. The total of identifiable high-risk groups because of existing diseases exceeds 20% of the

population. When age, smoking and poor nutrition are taken into account the figure is greater than one third. Figures in Canada are likely similar but require confirmation.

C. Medical Unknowns

The report points to two factors that contribute to the difficulty in interpreting the extent and seriousness of the health effects of indoor air pollution.

1) Most existing pollution standards have been based on industrial and outdoor factors. Neither reflect the long-term, continuous, low-level exposure that people experience indoors.

2) Pollution criteria, or the levels of exposure deemed hazardous, are based on studies of single chemical exposures. Very little is known about the synergistic or compound effects of complex mixes of air contaminants.

The report further states that the long list of medical unknowns indicates the need for literally decades of good research.

Among the unknowns requiring answers, the report includes the following;

- The characteristics and degree of indoor air pollution in Canadian housing.
- The number of Canadians now affected and the number of high risk.
- The range of possible health effects of long term, low-level exposure and the estimated number of people who could develop adverse symptoms over the long term.
- Methods to properly treat and rehabilitate those whose health has been impaired.

- The present and future social costs, including the impact on the health care system, attributable to indoor air pollution.

D. Pollutant Sources

The section on pollutant sources includes material oriented to the particular pollution source rather than to individual pollutants. The categories represent specific problem areas within homes and the potential subjects for focused research.

Each source is accompanied by a review of available scientific literature. A description of the source is followed by a listing of the pollutants produced and a discussion which quotes knowledgeable researchers in each category.

The pollution sources that are examined include:

- gas furnace chimneys
- gas stoves
- unvented gas and kerosene heaters
- oil and gas furnaces
- wood and coal furnaces and stoves
- outgassing furnishings and materials
- intrusion of outdoor pollutants
- use of household chemicals
- consumer appliances
- spray humidifiers
- paints and sealers
- insulation
- occupants' activities

Pollutant Source	Descriptive Summary
Improper Chimney Construction	Improperly lined chimneys may corrode from the exhaust of a natural gas furnace, leading to blocking and potentially fatal carbon monoxide accumulation in a home.
Gas Stoves	Gas stoves are major producers of carbon monoxide and nitrogen dioxide at rates which are harmful to health.
Kerosene Heaters	Portable unvented kerosene heaters produce carbon monoxide and other gases at levels considerably above outdoor standards, under normal operations.
Fossil Fuel Furnaces	Improperly installed or maintained fossil fuel furnaces can contribute to indoor air pollution, sometimes at dangerous levels. Chemically susceptible persons are more quickly affected by small leaks than others.
Wood Stoves	Burning wood can lead to high indoor pollutant levels if stoves are not well sealed or carefully operated. Infiltration of second-hand wood smoke from neighbouring chimneys can also increase indoor pollution significantly.
Furnishings	Many furnishings and decorative materials in the home are responsible for the presence of different organic contaminants in indoor air. While each individual source may appear innocuous, the total pollutant load may be significant for many people, and can definitely cause harm to those who are already chemically susceptible. Alternative products are needed.
Outdoor Pollution	Infiltration of various outdoor pollutants, especially car exhaust from adjacent roads and radon gas from soil beneath a home may present long-term health problems.
Household Chemicals	Many household products (e.g. cleaners) contribute significant quantities of organic chemicals to indoor air, and have been reported to trigger adverse symptoms in susceptible persons. The total load is important.

Pollutant Source	Descriptive Summary
Appliances	Numerous small household electrical appliances give off a variety of organic chemicals and odours. Some may be signficant sources of indoor pollution and are known to affect susceptible persons.
Humidifiers	Household humidifiers which either recycle their water or which include an open water reservoir which can stagnate can become sources of micro-organisms that will contaminate indoor air and could affect health.
Paints	Paint and sealers may release various organic gases, lead, and mercury. Some sensitive individuals can detect paint fumes for three months or more after application. Neurotoxic effects during painting may also increase risk of accidents.
Insulation	Various types of insulation in addition to Urea-formaldehyde form have been reported to cause some problems particularly for already susceptible persons. Extruded polystyrene, cellulose, and fibreglass are cited.
Activities	Normal processes of living and respiration by people and their pets generate a number of gases and particles. Very few daily activities do not involve addition of pollutants to indoor air in some form. Hobby activities often involve highly toxic materials.

E. Factors Aggravating Indoor Air Pollution

The existing literature was searched for evidence of specific factors which tend to cause an accumulation of indoor air pollution. Most recent literature concentrates on the role of energy conservation measures. The tightening of houses to conserve energy can reduce air change rates, increase humidity and lead to elevated levels of indoor air contaminents.

Research reports indicate that older houses may have natural air exchange rates on the order of 0.8 to 1.5 air changes per hour. Well constructed new houses have air exchange rates on the order of 0.5 to 1.0 per hour. A small number of state-of-the-art homes lower this rate to 0.2 to 0.5 air changes per hour.

Researchers have found inconsistent results when testing levels of indoor contaminants in new energy efficient residences. However, one theoredetical formula indicates large increases in indoor contaminants as air change rates drop.

Increased humidity may promote condensation and subsequent growth of mould, algae and fungi. High relative humidity also increases formaldehyde and other emissions from such materials as particleboard.

Similarly, high temperatures resulting, for example from direct sunlight can increase gassing-out rates among a variety of synthetic materials.

Although supporting literature was sparse, two other factors were mentioned. First, the likelihood of indoor pollution goes up with the number of people in any space. Venting should be matched to occupancy. Second, hundreds of new materials have been introduced into homes and have contributed substantially to the indoor air pollution problem.

F. Factors Reducing Indoor Air Pollution

The existing literature was searched for evidence of specific factors which tend to reduce accumulations of indoor air pollutants. In some instances material is sparse, reflecting the relative infancy of the science of low-pollution design. Overall, the factors fall into three broad categories.

The first involves design factors incorporated into new housing or retrofitted as a remedial measure in existing housing. These factors include;

Increased Ventilation	Increasing ventilation is effective in diluting indoor pollutants, but can increase energy costs. New heat exchangers may provide a means of keeping indoor air clean at less cost.
Decreased Ventilation	Occasionally reduction of general ventilation may be advisable in order to avoid infiltration of concentrated outdoor pollution (e.g. wood smoke).
Source Removal	Removing the source is most often effective, but can be expensive (e.g. UFFI removal). There can be difficulties in finding replacement materials that will not present further problems for persons who may already be generally chemically susceptible.
Modified Combustion Processes	Maintenance, adjustment, or redesign of indoor combustion sources may reduce emissions and/or ensure that emissions are properly vented to the outside.
Changes in Design	Ultimately a number of improved design and construction practices can help to reduce indoor pollution.
Air Filtration	Pollutants indoors can be reduced with gaseous and particulate contaminant filters. Practical problems of upkeep and annual cost must be solved. Those who need filtration most are least able to tolerate various filtration media.

Ventilation at the Source	Removing pollutants at the source is more effective for good air quality and better for energy conservation.
Warning Devices and Controls	Use of air quality monitoring devices and feedback systems to control mechanical ventilation may help to maintain better quality indoor air.

The second category deals more specifically with building and furnishing materials.

Adsorption of Interior Surfaces	A number of air contaminants either react with or are absorbed by various surfaces within a room. This can help reduce peak concentrations but absorbers may later become emitters.
Gassing-Out Time	Some materials or furnishings can be left to 'gas out' for a period prior to use, thus reducing pollutant exposure to building occupants.
Low-Emission Materials	Materials, appliances, mechanical systems, etc. can be selected with lower pollution emission in mind.
Use of Sealants	Some pollutant emissions can be curbed by sealing the offending surface (e.g. with a point or with an impervious materials as a barrier).
Adjustment of Product Formulation	Modifications may be possible in the constituents or in the manufacturing process of building materials and furnishings that pollute.
Treatment of Final Product	Additional treatment processes at the factory might reduce outgassing in the home.

The third grouping addresses factors related to use and includes;

Human Factor Control	Voluntary and deliberate reduction of polluting activities by an informed public may be one part of the solution. Individuals can exercise some choice.
Changes in Maintenance Practices	There is much scope for reduction of pollutant levels by reducing heavy reliance on volatile chemical produces, e.g. for cleaning.

G. Low Pollution Design and Construction

Indoor Air Pollution and Housing Technology describes the author's construction of a 560 m^2 experimental building near Goodwood Ontario. Designed to accommodate both the author's family and the facilities of the "Sunnyhill Low-Pollution Research Centre" the building aims at demonstrating the lowest possible levels of indoor air pollution.

A number of measures are described, which taken together produce the desired results. These include:

- o Flushing pollutants to the exterior requires general low level exhaust of room air, and the specific venting of appliances, bathrooms, electronic equipment and storage areas.
- o Exteriorizing and sealing pollutants requires airtight walls to eliminate infiltration of building material odours, controlled venting of all insulation materials to the outdoors, foil vapour barriers to reduce outgassing from insulation materials and other components such as plastic pipe and pipe cement, sealing of light fixtures from room air and the extensive use of ventilated storage cupboards.
- o Scrubbing indoor air with activated carbon or chemisorbant filters.
- o Substituting materials or systems to reduce the use of high gas-off products involved testing gas-off properties of materials and required the use of all-electric and solar heating.
- o Treating pollution sources to reduce emissions requires separate heat sources, venting and air filtration and additional air cleaning.
- o Isolation of affected individuals requires rooms with separate heat sources, venting and air filtration and additional air cleaning.

- o Meticulous attention to detail during design and construction phases ensures that the effect of the above measures is not undermined.

Ongoing monitoring and research has resulted in preliminary conclusions regarding the effectiveness of these techniques. The author plans to continue this effort.

The clinical areas of the building will be used for the training and rehabilitation of persons with extreme chemical susceptibilities under physician's care. Overall exposure levels are expected to be as low or lower than those afforded by clinical facilities operating in the United States.

The Sunnyhill Low-pollution Centre represents the most stringent end of a full spectrum of air quality standards and needs. The standard being sought at Sunnyhill is neither practical nor necessary for general application in conventional housing in Canada at the present time.

However, the report identifies the need for specific standards and guidelines to protect the general population from excessive indoor pollutants and as a means whereby high risk individuals can exercise some choice in the level of their indoor exposure.

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