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INDOOR AIR QUALITY RESEARCH IN CANADA

by D.S. Walkinshaw

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Section 13

INDOOR AIR QUALITY RESEARCH IN CANADA

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ABSTRACT

The quality of indoor air as it affects health has become an important issue in Canadian public and scientific circles where concerns have been closely linked to energy conservation measures. This paper outlines Canadian indoor air quality research as it is presently being developed in the context of the government-funded building energy conservation research program where it ranks as the top priority activity. While the primary effort is now on UFFI research, this will shift to the broader indoor air quality problem over the next few years and with this in mind, some priority activities are suggested.

INDOOR AIR QUALITY RESEARCH IN CANADA

Douglas S. Walkinshaw

INTRODUCTION

Concern about the quality of indoor air as it affects human health has grown rapidly in the last few years, in Canada as it has elsewhere. Specifically, there is concern about the day-to-day exposure of people to airborne contaminants in the office, school, and home - places where a large number of people spend by far the largest portion of their time. Whereas until recently outdoor air pollution has been the major focus, it is now recognized that there is an urgent need to turn our attention indoors as well. We are becoming aware that potentially hazardous gases such as carbon monoxide, nitrogen oxides, radon and formaldehyde, respirable suspended particles such as those from tobacco smoke, and viable particles such as fungi spores and microorganisms from plants, animals and people, can be generated and trapped indoors at levels significantly higher than those occurring outdoors.

The increasing tightness of new and retrofitted buildings, together with the chemical nature of certain building materials and consumer products, have raised serious concerns about the extent of the deterioration of indoor air quality as it affects human health. These concerns have been reinforced by the UFFI problem in houses and non-specific problems in some federal buildings. The extent of the indoor air problem due to off-oil measures and the resulting increased use of fuels such as wood and coal, and due also to reductions in enclosure leakage and mechanical ventilation, should be ascertained and resolved in the interests of health and safety.

The compelling financial and energy conservation incentives for tightening the enclosures of buildings and reducing ventilation rates in Canada are perhaps best illustrated by the cost data shown in Table 13-1. Here the present annual heating costs for a small ranch style bungalow in Ottawa are calculated as a function of insulation value and air change rate.

Table 13-1

ANNUAL HEATING COSTS FOR AN OTTAWA BUNGALOW

Insulation		Ventilation without heat recovery		
Walls	Ceiling	1 ACH	0.5 ACH	0 ACH
R12	R20	$ 1410	$ 950	$ 500
R20	R40	$ 1110	$ 660	$ 240

Heating Season: 8000 F degree days.
Floor area excluding basement = 1180 ft^2, Volume = 18,900 ft^3.
Thermostat setting: day = 70°F, night (11 p.m. - 6 a.m.) = 63°F.
Electric resistance heating at 4¢/kwh. Passive solar included.
ACH = air change per hour.

These costs illustrate the significant opportunities for savings through winter reductions in excess indoor-outdoor air exchange and exhaust air heat recovery. For this example, some $450 can be saved annually for a reduction from 1 to 0.5 ACH, and a further $225 for maintaining the remaining 0.5 ACH with 50 percent heat recovery. This yields a total saving of $675 annually. In comparison, only some $300 can be saved through a major upgrade in insulation. Of course, if the house were initially uninsulated, there would be more dramatic benefits from adding insulation.

Because of the many billions of dollars now being spent each year on health services in Canada (1), the potential savings related to improved indoor air quality surely need to be investigated. However, there is a question as to whether a significant proportion of our population will be very concerned about protecting themselves from the long term health effects of indoor pollutants such as radon. Radon cannot be detected by the senses, and at the levels occurring indoors supposedly represents a lower cancer risk than tobacco smoke, a pollutant to which many people still voluntarily expose themselves. To answer this, one needs to look at the attitudes of various segments of the population. There is, for example, a large group, perhaps 15 percent, which is considered to be allergic to some airborne physical or chemical agents. Some in this group tend to stay indoors more to minimize exposure to irritants such as pollens. Others consciously avoid tobacco smoke. Because of their increased awareness and sensitivities, people in the sensitive group might well be interested in improving the quality of their indoor air, not only to alleviate immediate sensory irritation but also to avoid longer term problems, given information on health risks versus pollutant levels, and the availability of control measures.

CANADIAN GOVERNMENT INDOOR AIR QUALITY ACTIVITIES

A summary of recent Canadian government indoor air quality-related activities is given in Table 13-2.

Table 13-2

RECENT CANADIAN GOVERNMENT INDOOR AIR QUALITY (IAQ) ACTIVITIES

Item	Description	Status
UFFI ban	- Ban on sale	Banned - Dec. 17/80
	- Gov't UFFI Centre to assist UFFI homeowners	Established June/81
	- Gov't financial assistance program for UFFI homeowners announced Dec 30/82	57,000 registered. 25,000 assisted at average of $4900.
Residential IAQ Health Criteria	- Prov. & Federal D.M.'s of health set up working group in 1981 to develop IAQ criteria and guidelines	Drafts produced for 15 indicators.
Research	- Building Energy Conservation research funding IAQ and UFFI research as top priority	UFFI research funded 1981. General IAQ research program started in Aug. 1982.
Federal Coordination	- Interdepartmental Committee on Toxic Chemicals to coordinate government activities	Terms of reference being established
National Building Code	- 1985 code to require mechanical ventilation capability of 0.5 ACH.	Passed standing committee on Part IX Housing & Small Buildings Feb. 1984

On December 17, 1980, the sale of urea formaldehyde foam insulation was banned in Canada. This ban has continued even though the United States, which banned UFFI sale for homes and schools in August 1982, removed its ban in April 1983. A government UFFI information centre to assist homeowners was established at Consumer and Corporate Affairs in June 1981 and an accelerated research program was begun at the National Research Council in the same year. A financial assistance program is in place to help any homeowner, whether suffering healthwise or not, to undertake remedial measures. To date some 25,000 homeowners have undertaken remedial measures, with an average government assistance of $4900. As part of the program, one-week formaldehyde levels in the living space plus wall cavity indicator levels of formaldehyde have been taken before and after remedial measures in each house. A further 32,000 homeowners have registered and could also be eligible for assistance.

In 1981, the federal and provincial deputy ministers of health set up a working group to develop indoor air quality criteria and guidelines for residential application which would account for potentially sensitive populations such as the young and aged. Information to form the basis for a pamphlet for the well-informed lay person should be completed this year. Seventeen (17) indicators are being considered. They comprise: carbon monoxide, carbon dioxide, radon and radon decay products, formaldehyde, aldehydes, nitrogen dioxide, microbiological agents, moisture, particulates, ozone, polycyclic aromatic hydrocarbons, chlorinated hydrocarbons, lead, pesticides, aerosols, synthetic fibres and asbestos, and oxides of sulphur.

In the summer of 1982 the Building Energy Conservation Sector (BECS) Committee of the federal Panel on Energy Research and Development (PERD) established indoor air quality research as its number one priority subprogram (2). The relative priorities of the six BECS energy research subprograms are shown in Table 13-3.

Table 13-3

FEDERAL BUILDING ENERGY CONSERVATION R&D PRIORITIES

Sub-Program	Low-Rise Residential Buildings	Commercial, Institutional and High-Rise Apartment Buildings
Indoor Air Quality	1	1
Design and Analysis	4	2
Heating and Cooling	2	5
Operating	5	3
Envelope	3	6
Lighting	6	4

In December of 1982, the Parliamentary Standing Committee on Health, Welfare and Social Affairs issued a report on UFFI in which they made a number of recommendations. One of these recommendations dealt with the indoor air quality concern. It stated, "The federal government should coordinate a comprehensive study on indoor pollutants and their potential health effects. Special reference should be made to the trend toward making buildings increasingly air-tight to conserve energy." (3).

In 1983, the federal government UFFI research program was further augmented and funded as a subset of the BECS indoor air quality subprogram. BECS subprogram budgets for the 1983 through 1988 period are shown in Figure 13-1. Values are in terms of 1984 dollars. The BECS funding for indoor air quality represents the major component of the total indoor air quality effort of the federal government at the present time.

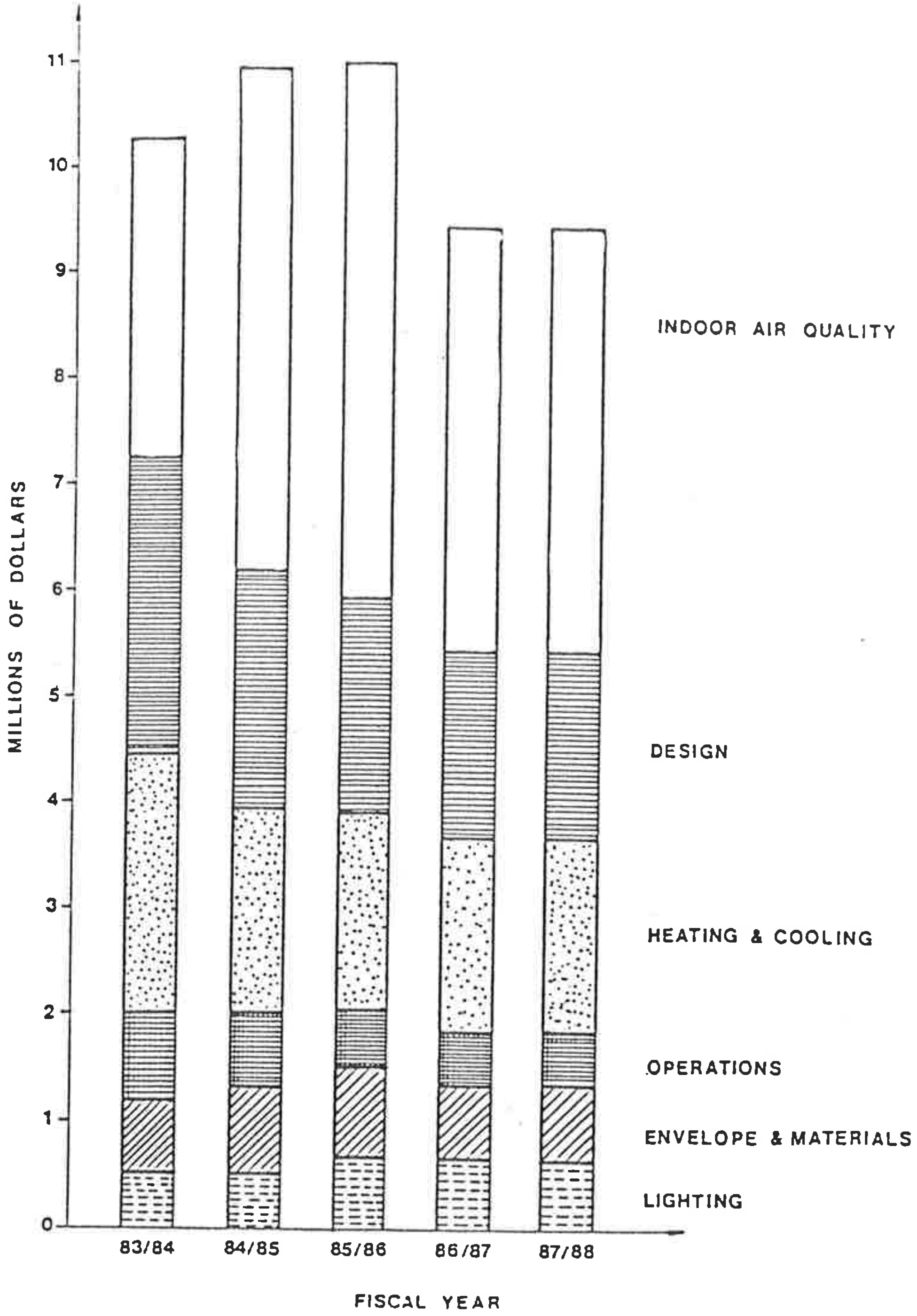

Figure 13-1. Federal Energy Conservation R&D Budgets by Subprogram

Also in 1983, the federal Interdepartmental Committee on Toxic Chemicals (ICTC) was identified as the overall coordinating body for federal indoor air quality activities. The ICTC is chaired by Environment Canada and the indoor air quality activity within it is coordinated by Consumer and Corporate Affairs.

In February 1984 the Standing Committee on Part IX, Housing and Small Buildings, recommended that the 1985 edition of the National Building Code require that new houses have a mechanical ventilation capacity of 0.5 ACH in the heating season, and if there are no openable windows, 1 ACH in the cooling season or 0.5 ACH with air conditioning.

CANADIAN GOVERNMENT INDOOR AIR QUALITY RESEARCH

Six departments are involved at this time in indoor air quality research under PERD/BECS funding (4). Health and Welfare are leading health research; the National Research Council is leading building science and engineering research; Energy Mines and Resources are performing furnace emission research and, along with Canada Mortgage and Housing and Indian and Northern Affairs, are involved in studies of houses; and Public Works Canada are studying office buildings.

Elements of an indoor air quality technology development and transfer program might be depicted as shown in Figure 13-2. This particular perspective is meant to be viewed from the centre outwards, focussing initially on four major activity sectors which are defined in ever-increasing detail as one moves outward in the sectors. The four major activities are:

- to evaluate and develop indoor health criteria and guidelines;
- to identify indoor air quality contaminant levels and their sources in buildings;
- to evaluate and develop indoor air quality control measures; and
- to transfer technology.

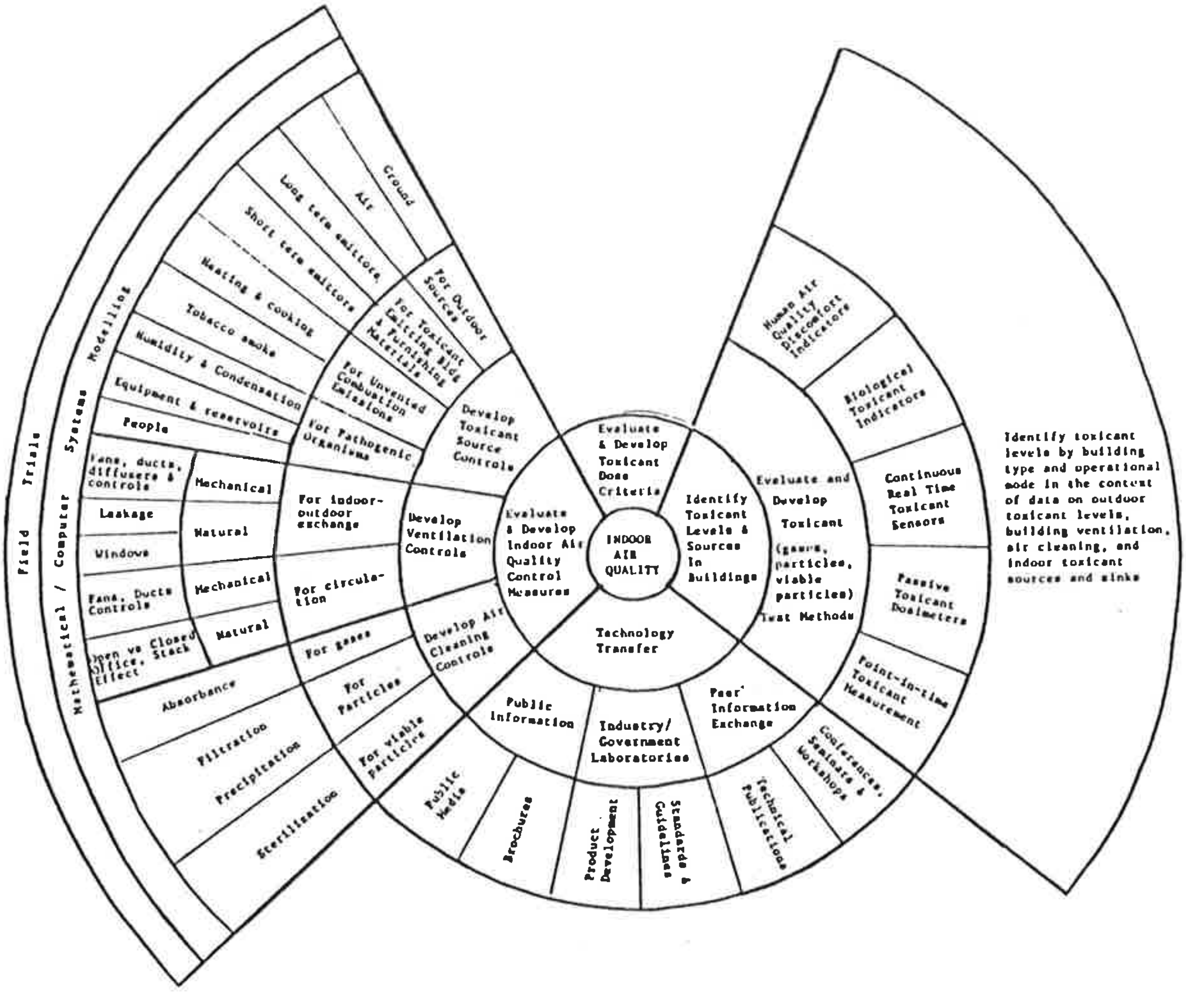

Figure 13-2. Some Elements of an Indoor Air Quality Technology Development and Transfer Program

A summary of BECS-funded indoor air quality research is given in Table 13-4.

Table 13-4

CANADIAN GOVERNMENT INDOOR AIR QUALITY (IAQ) RESEARCH ACTIVITIES

Research Element	IAQ Indicator	Activity
Test Methods Development	• Trace gases • Particulates • CH_2O • Organics • General • Emission rates vs Environment	GC/MS, MS/MS SEM, TEM, FTIR Dosimeters Badges Biological indicators Dynamic chambers
Field Measurements	• CH_2O, Rn, NO_2, ACH • General IAQ Indicators	Tight houses, electrically heated houses, UFFI houses. Federal office buildings.
Source Controls	• UFFI emissions (CH_2O)	UFFI removal, sealing, ventilation, trace gas and particle identification, classification by degree of hazard.
	• Combustion Products (gases, particulates)	Air flow characteristics and deterioration of chimneys; gas stoves with and without fume-hoods; kerosene heaters.
	• Radon	Parameters affecting soil gas entry into basements.
	• Particle board (CH_2O) • Polyurethane trace gases	Techniques to reduce emissions. Trace gases from insulation.
Ventilation Controls	• Indoor/Outdoor Air Exchange	ATAHE. Exhaust air heat pump recovery. Effects of induced draft and condensing gas furnaces. Passive ventilation. Effects of retrofit sealing. CO_2 control of theatre ventilation.
Health Studies	• UFFI emissions • 17 indicators • Pollutants augmented by off-oil and energy conservation	Clinical & epidemiological studies. Criteria and guidelines. Energy efficient homes, families with lung cancer fatalities. Toxicological & metabolic studies on benzaldehyde.

INDOOR AIR QUALITY CHALLENGES

As a result of information collected to date, there now are some specific indoor air quality-related concerns that appear to merit the concentrated efforts of the science and engineering communities. Among the challenges being presented, one set of priorities might be:

- To select the most appropriate remedial measures for UFFI residences.
- To define the health risks for typical indoor exposures to passive tobacco smoke, radon and formaldehyde.
- To develop low cost, reliable indoor air quality sensors for monitoring indoor environments.
- To ensure safe combustion product venting in residences.
- To provide effective ventilation of tight-enclosure residences and office buildings.
- To control formaldehyde levels in new, tight-enclosure residences.
- To control indoor tobacco smoke levels.
- To control indoor radon levels.
- To control indoor biological agent production.
- To develop a data base on indoor air contaminant sources.
- To provide education.

A brief rationale for the selection of these priorities follows.

Priority 1: Remedial Measures for UFFI

Remedial measures supported by the Canadian government for houses with UFFI include removal, inner space sealing from the wall cavity containing the UFFI, and added mechanical ventilation systems. The effectiveness of these remedial measures is being gauged by changes in occupant health symptoms, and in room air and wall cavity formaldehyde levels. The challenge is to ensure that these measures are the most effective, both now and for the longer term.

Priority 2: Exposure Level Criteria

Data now collected indicate that a significant proportion of the population is being exposed indoors to low levels of tobacco smoke, radon in basements and formaldehyde, low that is in comparison with occupational or voluntary exposure levels. While all the pertinent cause and effect relations of these agents on human health have not, as yet, been established, some of the exposure levels could be considered to be dangerous. For example, nearly 50 percent of the houses studied by Dumont (5) had levels of radon and/or formaldehyde in excess of guidelines. Standards embodying maximum permissable levels for long term exposure to these pollutants for various population groups should be agreed and set.

Priority 3: Indoor Air Quality Sensors

Low cost sensors and measurement techniques are being developed for research and survey purposes for measuring ongoing indoor pollutant exposures, ventilation characteristics, and humidity levels. Increasingly, building occupants will desire their own instruments to measure and control indoor pollutant levels. The challenge is to develop low cost, reliable, real-time sensors to monitor levels of key indoor air contaminants and air quality indicators.

Priority 4: Combustion Product Ventilation

Carbon monoxide poisoning as a result of combustion venting failures may result in some ten to twenty deaths yearly in Canada (6). As residential enclosures are tightened, exhaust fans for kitchen ovens are added, and supplementary heating systems such as wood stoves and fireplaces are introduced, the danger of chimney flow reversal increases due to an inadequate supply of air. It seems questionable practice that passively-vented furnace systems should be forced to compete for air with fireplaces and exhaust fans. The challenge is to develop furnaces with their own combustion-product venting fans and fail-safe flow reversal detectors, or with their own source of combustion air.

Priority 5: Ventilation of Tight-Enclosure Houses and Office Buildings

Over the years there has been a tendency to build houses with increasingly tight enclosures as insulation levels have been increased. This trend is illustrated by the data in Table 13-5 that have been collected by Dumont and Orr (7) for some Saskatoon houses.

Table 13-5

COMPARISON OF AIR LEAKAGE CHARACTERISTICS FOR GROUPS OF SASKATOON HOUSES

Type	Leakage Area m^2	ACH at 50 Pa	Number of Houses
Pre-1945	0.1078	10.35	19
1946-1960	0.0709	4.55	20
1961-1980	0.0621	3.57	97
Special air-tight homes 1977-1980	0.0330	1.49	40

More recently, there have been further significant advances in building houses with very tight enclosures and eliminating "unnecessary" chimney leakage. Air exchange through chimneys when furnaces are not operating can account for a significant portion of overall air exchange (typical chimney opening is 0.04 m^2) and provides a means for exhausting pollutants from basements. With respect to envelope tightening, in one recent series of demonstration houses the passive air change was assumed to constitute no more than 0.05 ACH. These houses must rely on mechanical ventilation, in this case with heat recovery. Many existing houses have been tightened to the 0.2 to 0.5 ACH range. In general, new houses are being enveloped in polyethylene above and below grade, including such details as electrical outlets. In most houses, leaks around windows have been caulked and doors weatherstripped. Extremely low conductivity windows are being developed for homes of the future which will remain closed permanently, similar to those of the modern office building.

Normally, indoor air quality concerns are greatest for the winter period when windows are usually closed. However, a study in Toronto by Manley, Helmeste and Tamura (8) of 12 electrically heated forced warm-air system houses with air conditioning showed that radon and formaldehyde levels were higher in summer than winter. The main reason was thought to be the low house air change rate during the air conditioning season in comparison with that during the heating season when the stack effect is greater.

Concerns and challenges arising in connection with tightening house enclosures include:

- The need for a secure and separate supply of combustion air.
- The need for a reliable data base on year-round air change and internal circulation rates on which to base pollutant level and health impact assessments for the changes occurring.
- The unknown relationships between air change rates and indoor air pollutant levels.
- The absence or controversial nature of indoor air quality contaminant criteria for long term exposures.
- The need for passive back-up to mechanical ventilation devices that can fail due to power interruptions or equipment malfunction.
- The fact that people may control mechanical ventilation devices in ways that are less healthful than they have experienced in the past with passive ventilation or openable windows, particularly if they are not given guidance.

Similar concerns and challenges apply to office buildings with fixed windows where occupants must rely on central mechanical heating and cooling systems for their ventilation requirements.

Priority 6: Control of Formaldehyde Levels

Formaldehyde is emitted from a number of materials and products, including particleboard and other formaldehyde resin bearing materials. Therefore, formaldehyde levels are more likely to be elevated in new houses where these materials tend to be more prevalent and the envelope tends to be tighter.

Dumont (5) has studied formaldehyde, radon and nitrogen dioxide levels in 46 tight-enclosure houses built in the last few years in Saskatoon. Some of these houses had air-to-air heat exchangers. The median level of formaldehyde was 0.09 ppm, with 18 of the houses having levels above 0.1 ppm. These values are higher than those recorded in the Canadian UFFI survey of October 1981 (9) for either the average of 1928 UFFI houses or 383 non-UFFI control houses. These houses had average formaldehyde levels of 0.054 and 0.036 ppm, respectively. Shirtliffe et al (10) reported that the 3-hour impinger method used in 1981 for many of the survey measurements gave generally lower values than those measured with 7-day dosimeters and that the higher levels are likely more representative. Since then average formaldehyde levels recorded in various UFFI houses in 1982 were in the 0.07 to 0.08 ppm range, and in early 1983 in the 0.04 to 0.05 ppm range.

The challenge is to reduce formaldehyde levels in new, tight-enclosure houses in the most cost effective manner. This may be through some combination of control at source, ventilation and air cleaning. The work of Matthews et al (11) at Oakridge suggests that increased ventilation alone may not be effective and that the amount of formaldehyde-emitting material permitted for given rates of emission may have to be controlled.

Priority 7: Control of Tobacco Smoke Levels

Tobacco smoke contains some 3800 compounds, over 50 of which are known or suspected to be toxic or tumorgenic agents. In 1981, 7.4 million Canadians smoked an average of 27 cigarettes/day (12). This represents 39% of the population 15 years of age and older, and is the highest rate among the industrialized nations. In comparison, in the same year in the U.S., 34% of the adult population smoked 22 cigarettes/day.

The challenge is to develop the most effective air cleaning devices and ventilation-near-source office building designs to reduce passive tobacco smoke exposure.

Priority 8: Control of Radon Levels

The main source of radon indoors is thought to be the soil surrounding the basement of houses. Eaton and Scott (13) suggested that the radon level in houses from soil sources is primarily a function of the radium concentration in the soil, the house air change rate, and the soil permeability. They postulated that radon will readily enter basements if there are crack areas greater than 1 cm^2. Dumont (5) found that 12 of the 44 tight-enclosure houses tested in Saskatoon had radon levels greater than 4 pCi/L, while the median level was 3 pCi/L.

The major challenge with respect to radon control appears to be the development of better ventilation techniques, particularly for the basement area, along with cost-effective methods for preventing radon entry into basements.

Priority 9: Control of Biological Agents

Biological agents cause allergic and infectious illness. Bacteria, moulds, and fungi grow on wet surfaces and in stagnant bodies of water. With the tightened enclosures and elimination of chimneys and openable windows, the potential for condensation of indoor humid air on cold enclosure surfaces in the winter is enhanced. With the introduction of whole-house mechanical ventilation devices, there is an increased chance of house pressurization causing further condensation potential. Houses on our east and west coasts may have more potential for these problems due to their wetter climates. The extent of this problem remains to be defined.

Studies on stagnant bodies of water, whether humidifiers, hot water tanks or pools of water under bath tubs from shower spray, also need to be undertaken to ascertain their potential to cause indoor air quality problems. Appropriate measures should be developed for regular disinfection and dust removal, and new designs created which avoid the problem in the first place.

The question of appropriate indoor humidity, winter and summer, and its control needs to be studied from both health and building science perspectives.

Priority 10: Characterization of Indoor Air Contaminants

Indoor environments in general seem to contain a much larger number of measurable gaseous compounds than occur outdoors. The origin of these gases needs to be ascertained and studies of their primary sources carried out to determine how emission characteristics vary with age, temperature, humidity, air change rate, barometric pressure, wind speed, and pollutant concentrations, and the relative effectiveness of surface emission sealants, material "cleaning," air cleaning and ventilation measures. In addition to gases, there have been concerns expressed about the prevalence of respirable synthetic and asbestos fibers indoors.

The challenge is to develop a data base on building material and consumer product emission characteristics so that consumers, building designers and building managers can work at improving the base level of their indoor air quality. Since health scientists have expressed concerns about possible synergistic and interactive effects of pollutants, reduction of this background indoor air quality "noise" may actually have a very significant impact.

Priority 11: Education

There are a number of areas for which indoor air quality knowledge and technology are available, and consumers and building designers and managers simply require education. For example, the operation of proper range hoods venting to the outdoors would appear to relieve concerns about cooking with gas stoves (14). However, the use of unvented combustion devices for space heating introduces pollutants into the living space whose dilution depends upon room ventilation rates which can vary considerably. Even if products of combustion from these devices do not reach levels exceeding health and safety criteria, there are alternative portable devices such as electric resistance heaters which will normally fulfill the same function without contaminating the air. The application of oil paints to school interiors during the winter school session rather than during summer recess seems to make little sense from the indoor air quality viewpoint. The use of paint strippers, etc., should only be carried out in an area with a very high ventilation rate. Unfortunately, many such activities are often carried out in inadequately ventilated basements. Household vacuuming suspends respirable particulates so that sensitive persons might need to wear filtration masks during this operation. Designers should ensure that building make-up air is not contaminated by its exhaust air. The arrangement, rearrangement and selection of open office screens needs to be coordinated with the placement of air diffusers and air circulation requirements. If variable air volume heating and cooling systems are to provide ventilation air as well, they should be designed to do so at adequate rates.

CONCLUSION

Indoor air quality problems are not a new experience for man. Dr. R. Munn, in a 1972 background paper on air quality for the Science Council of Canada, pointed out that Algonquin Indian women frequently went blind by the age of 30 from the smoke and fumes in the cooking areas of their long houses (15). In the same article, Dr. Munn pointed out the complexity of the subject, noting that the response of living organisms to pollutants is not well understood and that there can be adaptation as well as synergistic effects. He went on to observe that in an area like air quality where measurements are being made to the limit of equipment sensitivities, scientists tend to study what they can measure with the instruments to which they have access rather than pursue the contaminants that might be the real cause for concern.

In commenting on recent developments in the field of analytical chemistry with the ever-increasing sensitivity of instruments down to the parts-per-billion or trillion range and beyond, Dr. David Wiles, Director of the National Research Council's Division of Chemistry, cautioned that the effects that minute traces such as these could possibly have on health and safety must be assessed with great care and in a proper persective (16).

I believe we should bear such wisdom in mind as we proceed with our indoor air quality research programs. Let us not become alarmists and publicity seekers, but instead endeavour to put indoor air quality into its proper perspective through an increase in our scientific understanding of the problem.

ACKNOWLEDGMENT

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