RESIDENTIAL INDOOR AIR QUALITY GUIDELINES

R.S. Tobin, M. Bourgeau, R. Otson, G.C. Wood
Bureau of Chemical Hazards,
Environmental Health Directorate,
Department of National Health and Welfare
Ottawa, Ontario, Canada

ABSTRACT

Indoor air quality is of prime importance to human health because we spend >80% of out time indoors. Occupants of indoor environments may be exposed to a variety of pollutants originating from human activities or presence in the home, combustion for heating and cooking, consumer products, furnishings, building materials and outdoor air. Because of the potentially adverse effects to human health resulting from exposure to pollutants in the home, the "Exposure Guidelines for Residential Indoor Air Quality" were developed. Exposure limits were prepared for the following compounds or groups of compounds: aldehydes, carbon dioxide, carbon monoxide, formaldehyde, nitrogen dioxide, ozone, particulate matter, sulphur dioxide, water vapour and radon. In addition, the guidelines suggest recommendations for controlling exposure to some contaminants for which the formulation of acceptable exposure ranges was deemed inappropriate or was not feasible. This group includes: biological agents, chlorinated hydrocarbons, fibrous materials, lead, pest control products, polycyclic aromatic hydrocarbons, product aerosols, and tobacco smoke.

Review of five substances (xylenes, toluene, 1,4-dichlorobenzene, benzene, and tetrachloroethylene) to determine potential health risks has revealed the primary route of exposure through indoor air. They will be considered for guideline development and possible inclusion in the existing Exposure Guidelines for Residential Indoor Air Quality.

Health and Welfare Canada has an active research program including a variety of projects: a survey of the occurrence of selected volatile organic compounds in Canadian residences representing a range of energy efficiencies; development and evaluation of analytical methods for measurement of human exposure to airborne organics; a study to measure home dampness and molds to validate the observed association between respiratory health and indicators of home dampness; and participation in projects related to energy conservation and air quality as part of the research program of the Panel on Energy Research and Development (PERD).

Introduction

Air pollution has long been recognized as a threat to health. It has probably generated more public interest in environmental quality than any other form of environmental degradation. Smoke and odours from coal combustion were regarded as public nuisances as early as the fifteenth century. Most industrialized countries have a history of legislation to control emissions from point sources that extends back many years.

It is curious, therefore, that indoor air has only recently become the focus of intensive research and debate. This recent activity attests that indoor air quality has become an important health concern particularly when it is taken into consideration that we spend as much as 80-90% of our time in enclosed spaces (1).

Here in Canada, the public's attention to indoor air quality was perhaps concentrated most by the controversy surrounding urea formaldehyde foam insulation (UFFI) and its ban by the government in 1980. Concern has persisted owing to the reporting of scientific studies that show chemical contaminants in indoor environments at concentrations higher than those occurring outdoors (2) and because of office workers' claims that poor air quality in large office buildings is a result of energy conservation practices. The focus of this paper is on the Guidelines for the Residential Indoor Air Quality, with particular reference to the home environment as a source of exposure to airborne contaminants.

The quality of indoor air depends both on the quality of outdoor air and on the strength of emissions of indoor sources. In most inhabited spaces, there is a continuous exchange of air with the outside. Therefore, all contaminants of outdoor air are likely to be present indoors. The main pollutants in this category include:

- carbon monoxide
- nitrogen oxides
- sulphur oxides
- particulate matter
- hydrocarbons
- ozone and other photochemical oxidants
- lead

These pollutants originate mostly from motor vehicle and factory emissions and other combustion processes. In the absence of indoor sources of these contaminants, their indoor concentrations will tend to be close to or lower than outdoor concentrations. Sulphur dioxide, ozone, sulphates, nitrates and lead concentrations, for example, are usually lower than those outside because of their reactivity and surface adsorptions.

All internally generated airborne pollutants ultimately result from human activity or choice. These contaminants can be classified as follows:

- those related to human activity or presence;
- those formed in combustion processes for heating and cooking;
- those derived from construction materials and furnishings;

Concentrations of contaminants in the first two categories tend to vary with time. Those in the third are likely to be more constant, provided that air exchange rates remain constant. Thus, control stategies for these groups are likely to be different.

(1) Pollutants Related to Human Activity or Presence

The variety of contaminants resulting from human activity are very broad. Air fresheners, furniture waxes, polishes, cleansers, paints, pesticidal formulations, fabric protectors, and deodorants are products frequently used in the home and are sources of various inorganic and organic chemicals. Many substances found in the workplace may also occur in the home as a result of hobby or craft activities. For example, paint strippers contain methylene chloride, cleaning solvents comprise a mixture of aliphatic hydrocarbons and certain glues can release toluene. Exposure to metal fumes may result from welding, soldering and metal working operations.

Human metabolic activity itself influences air quality by reducing the concentration of oxygen and increasing levels of carbon dioxide. Respiration, perspiration and food preparation add water vapour as well as odour-producing substances to the indoor environment.

Smoking is a major source of indoor air pollutants. While smokers subject themselves to mainstream smoke, bystanders can be involuntarily exposed to significant amounts of respirable particles, carbon monoxide and oxides of nitrogen in sidestream smoke. Other potentially harmful contaminants in sidestream smoke include PAHs, phenols, nicotine, nitrosamines and aldehydes. More than 3,000 constituents have been identified in cigarette smoke, of which about 150 are biologically active.

(2) Combustion Processes

One of the major potential sources of combustion by-products in Candian homes are gas-fired appliances. Typically, oven and pilot light emissions are not vented and can contribute significantly to indoor levels of carbon monoxide, nitrogen oxides and formaldehyde.

Of emerging interest as a potential source of indoor air pollution is the wood burning stove. Since combustion is much less complete with wood than with oil and gas furnaces, pollution emissions can be greater. Though by-products should be vented to the outside, leaks and improper operation of these appliances can cause emissions to the indoors. Contaminants associated with wood burning stoves and fireplaces include carbon monoxide, oxides of nitrogen and sulphur, aldehydes, phenols and PAHs.

Kerosine heaters are becoming increasingly popular for space heating. Since these systems are often unvented, the potential for high level contamination exists. In particular, the improper use of high-sulphur-containing fuel or poorly designed units could result in emission of sulphur oxides as well as some of the combustion by-products previously mentioned.

(3) Building Materials and Furnishings

Synthetic polymers used in furnishings and decorative materials can undergo slow degradation releasing small quantities of contaminants. Draperies, rugs and fabrics, most of which are synthetic, are sources of a variety of organic and microbiological contaminants. Formaldehyde is released from wood laminates and particleboard in which formaldehyde-containing resins have been used. Urea formaldehyde foam insulation is a significant source of formaldehyde and possibly other gaseous products. Insulating materials such as fiberglass can release particulate matter to indoor air. An important fibrous contaminant is asbestos which is present in electrical and insulating products, sprayed-on acoustical material, spackling and patching compounds, as well as asbestos cement tiles.

One particular contaminant which warrants immediate consideration, specifically in tightly sealed buildings, is the radioactive gas radon-222. This gas is emitted from construction materials such as bricks, concrete, rock aggregates, plaster and mortar mixes. Domestic water, natural gas, underlying soils and groundwater also can release substantial amounts of radon to the indoor atmosphere. Radon gas decays by a series of steps, involving emissions of alpha particles to yield lead-210. It is the inhalation of radon's decay products, and therefore exposure to alpha radiation, which is of concern to human health.

The simple presence of these contaminants does not in itself constitute a human health hazard. The actual degree of risk depends on the levels and duration of exposure, as well as the susceptibility of the individual.

In Canada, no single agency or organization has sole responsibility for investigating and controlling the potential health impact of residential indoor air pollutants. Moreover, in the case of residential buildings, involvement by government may, on one hand, be viewed as an intrusion and, on the other, as a necessity. There are a number of national agencies in Canada that have a role to play in this regard. These include:

- Department of National Health and Welfare
- Department of Public Works Canada
- Department of Energy, Mines and Resources
- Canada Housing and Mortgage Housing Corporation
- Division of Building Research, National Research Council of Canada
- Department of Consumer and Corporate Affairs
- Housing and Urban Development Association of Canada
- Canadian General Standards Board

The complexity of the situation is well illustrated by the wide variety of strategies and approaches that are possible for controlling the exposure to airborne pollutants that may be present in the indoor environments. Ultimately, the control of indoor air pollutants must be achieved through measures such as ventilation, source removal or substitution, source modification, source avoidance, air purification, restrictions on the use of potentially hazardous chemicals in the home, certification programs for builders and trades people, mandatory courses for engineers and building designers, and educational programs for the public.

These approaches may not be mutually exclusive and corrective measures could involve a balanced application of several or all methods. The extent to which controls need to be exercised should be determined to a large degree by specifications, or criteria, which define a quality of air that is conducive to good health and comfort. It was for this reason that the "Exposure Guidelines for Residential Indoor Air Quality" were developed. Although these guidelines have been approved by government departments across the country, they are not mandatory or enforceable as standards. They are intended to assist individuals and public agencies in making consistent judgements about the need for remedial measures. In the longer term, it is anticipated that the national guidelines will be used as a basis for developing or modifying building codes, product standards for construction materials and furnishings, and ventilation requirements.

It is important here to note the nature of the Guidelines and to be able to distinguish them from standards. Standards are defined as "prescribed levels, quantities of values which are regarded as authoritative measures of what is a safe enough, or acceptable amount of contamination, or exposure to risk". Depending on the legal framework which exists (this may vary according to the responsible provincial or federal agency), standards are usually codified in regulations and carry with them the power of legal enforcement. Guidelines on the other hand, may be viewed more as recommended levels and do not have a legal backing to ensure compliance.

The Department of National Health and Welfare does not have the legal mandate to establish standards or regulations to control the quality of air in private dwellings. However, under the Department of National Health and Welfare Act, general authority is given to the Department to conduct research, to publish information and to provide advice on matters relating to public health. As an example of the latter, it is the responsiblity of Environment Canada to regulate, under the Canadian Environmental Protection Act (CEPA), emissions of hazardous pollutants to ambient air. Such measures may however be implemented on the recommendation of the Department of National Health and Welfare as this Act involves both ministers.

It should be stressed that the Canadian exposure guidelines are intended to apply to the residential setting and not to other indoor environments such as office buildings or work places where factors such as multiple occupancy may be important. Because many conspicuous problems have to do with air quality in non-residential settings, a second Federal-Provincial Working Group was struck to develop a manual for the investigation of indoor air quality problems in such buildings. They will develop recommendations for an action plan to deal with the issue. The final products will consist of a protocol and a technical guide on the investigation of indoor air quality in office buildings. The reports will provide a review of indoor air quality investigations in office buildings and up to date good practice for investigating complaints when the source of the problem is not obvious. This project involves cooperation between National Health and Welfare, Public Works Canada and the Provinces and is in its final stages of publishing.

About the Guidelines

The Guidelines were formulated with the objective of protecting the health of most people including susceptible sub-groups: the very young, the elderly, and those with pre-existing health problems. These groups are especially of interest with respect to indoor air quality since they spend most of their time indoors. Two broad objectives were set:

1. To develop guidelines for the concentrations of selected contaminants in residential indoor air, taking into account such factors as the sensitivity of groups at special risk and the sources and mechanisms of action of contaminants.

2. To develop, where practicable, other guidelines or recommendations for measures that will preserve or improve air quality in domestic premises.

Individuals at special risk were defined as "those whose physiological processes are either not fully developed or are deteriorating or for whom pathological or physiological changes may impair the ability to surmount the adverse effects of exposure to a pollutant". The Working Group recognized that the exposure guidelines may not provide complete protection for the allergic or hypersensitive population. The second objective was established on the basis that lifestyle factors and actions taken by the homeowner or occupants can have a significant impact on affecting the quality of air in the home.

Selection of Substances for Guidelines

Seventeen substances were originally chosen for inclusion in the Guidelines. Radon was added in 1989. Selection criteria included their potential to adversely affect health, their representation of the categories of pollutants that might be present in the home and the availability of information from which recommendations could be formulated. It was realized that the list did not fully represent the range of compounds found in the home and that guidelines for additional substances would eventually be developed as new data became available.

The guidelines encompass two categories of contaminants. Sections A and B of the report deal with contaminants for which recommendations are expressed in terms of concentration ranges, specifically with reference to substances with non-carcinogenic and carcinogenic effects. Limits are specified for the following substances:

- aldehydes
- carbon dioxide
- carbon monoxide
- formaldehyde
- nitrogen dioxide
- ozone
- particulate matter
- sulphur dioxide
- water vapour
- radon

Section C deals with those contaminants for which the formulation of acceptable exposure ranges was deemed inappropriate or was not feasible due to lack of data or too broad a category and suggests recommendations for controlling exposure. This group comprises:

- biological agents
- chlorinated hydrocarbons
- fibrous materials
- lead
- pest control products
- polycyclic aromatic hydrocarbons
- product aerosols
- tobacco smoke

Recommendations for practical measures that should reduce or eliminate exposure in the home are provided for these substances.

An important consideration in deriving exposure guidelines for air quality is the possibility of interactive effects, since many pollutants are likely to be present simultaneously in the home environment. Where possible, the potential for synergistic and additive effects was considered in deriving the guidelines. However, in most cases there was insufficient data to adequately address this aspect.

Approach used in Establishing Recommendations

For all contaminants, a detailed search of the relevant scientific literature was conducted and a comprehensive review document was prepared. For each of the contaminant, information was assembled under the following headings;

- physical and chemical properties
- analytical methods
- sources and exposure
- pharmacokinetics
- health effects
- existing standards and guidelines
- conclusions and recommendations

Physical and Chemical Data

Such basic data are useful for understanding the spatial distribution of each substance in the indoor environment and hence of the potential routes and patterns of exposure.

Analytical Methods

The Working Group reviewed the analytical methods available for each substance or group considered. Most of the methods with respect to specific substances have been developed for the use in the study of either ambient air or of air pollutant concentrations in the workplace. The group considered that development of methods suitable for measuring concentrations of pollutants in domestic air is of great importance if further advances are to be made in the planning and control of indoor air quality. Both the American Society for Testing and Materials (ASTM) and the Canadian General Standards Board intend to standardize monitoring procedures for indoor air quality. There has also been a general attempt to standardize monitoring methods in the office environment through the publication of guides and protocols in collaboration with the Department of Public Works.

Sources and Exposure

The group reviewed the sources of each pollutant both outside and inside the house, and the effects of outdoor levels on indoor air by infiltration, to assist in identifying possible strategies for controlling domestic exposure. A review of information on exposure levels in typical housing was also conducted.

Pharmacokinetics

This covers the uptake of each pollutant, its distribution within the body, the metabolic changes which it undergoes, and its mode of excretion. This area is of great significance when reviewing the pathways whereby persons may absorb the pollutant in question. In general, when considering air quality, the primary pathway is inhalation. But in certain cases, there has to be careful evaluation of other possible ways of absorption such as ingestion (as in the case of lead) or through dermal exposure (as in the case of certain pesticides).

Health Effects

Although indoor air quality has received widespread interest as of late, reliable information on the health effects of exposure to the low levels and mixtures of contaminants found in the indoor environment is still inadequate. These studies are the cornerstone on which the development of any guidelines or recommendations must be made. In most cases, the results of laboratory experiments using animals, clinical studies with human volunteers, and epidemiological investigations of populations in the urban and occupational environments were used as a basis for developing the numerical guidelines. The principles followed in the evaluation of the results of these different types of studies as a basis for the recommended indoor air quality guidelines are as follows:

1. Epidemiological Studies - Most of the relevant epidemiological studies of populations are observational (non-experimental) in nature and are either of the descriptive (cross-sectional) or analytical (cohort or case-control) type. Several features must be taken into account in order to properly evaluate the results of these studies. Estimation of exposure is always of concern since exposure can vary greatly between individuals living in the same neighborhood due to differing climatic conditions and unique features of indoor environments (i.e. use of unvented combustion appliances). Confounding variables also play a role in misrepresenting exposure since variables such as smoking, occupational exposure, and meteorological factors can often have greater effects than exposure to the actual air pollutants. Measurement of outcome is also a feature that can produce a variability in results because of different methods of measurement of health parameters such as lung function, hospital admissions and frequency of symptoms. Many studies rely on tools such as questionnaires to measure outcome which is often subject to bias. For these reasons, epidemiological studies which control for confounders, in which objective health outcomes are determined, and in which variation in personal exposure is taken into account, are considered most relevant.

2. Clinical Studies - Clinical studies are often used to provide a basis to derive an accurate exposure-response relationship for which to set standards. However, they are limited, for obvious ethical reasons, to the measurement of mild, temporary effects of short term exposures to one or a few pollutants in a limited number of subjects. Studies which use the "double-blind technique" are preferred.

3. Animal Studies - Despite the fact that the large number of animal studies performed are at levels much higher than actual exposure, extrapolation of these results to man continues to be very complicated due to physiological differences. Exposure usually involves one or two pollutants at high concentrations as opposed to a typical situation where exposure would involve low concentrations of various pollutants. Animal studies are often more useful in clarifying mechanisms and routes of toxicity as well as determining the potential for carcinogenicity.

Existing Standards and Guidelines

Generally speaking, very few standards exist for the non-industrial indoor environment.

There are recommendations for ambient air and for exposure to airborne pollutants in the workplace. These were used as a reference point for the Working Group's guidelines.

Types of Limits and Definitions

As already mentioned, exposure limits have been set for 10 of the 18 pollutants reviewed. Research into the health effects of residential indoor air quality is at an early stage and there is therefore a dearth of reliable information on the health effects which result from exposure to the low levels and mixtures of contaminants likely to be found in the home. Consequently, in developing guidelines the Working Group had to rely largely on the results of the more traditional studies of air pollutants - that is, epidemiological investigations of urban air pollution. The results of animal studies and studies in which human volunteers participated, (i.e. clinical studies) were also used.

Both the possibility for acute health effects, and hence the need to develop short term exposure limits, and the possibility for effects which result from long term exposure to low concentrations of indoor contaminants were addressed. Decisions on whether to develop short or long term exposure guidelines, or both, depended upon whether results from suitable health studies were available. Acute effects were considered only if there was the likelihood of short term peak values in dwellings. Such possibilities are possible, for example, in the case of nitrogen oxides from gas stoves, and whenever household products such as aerosol sprays, spot removers and cleaners are used in poorly ventilated areas.

The Working Group defined the "Acceptable Short Term Exposure Range" ASTER as that concentration range to which it is believed from existing information that a person may be exposed over the specified time period without undue risk to health. The "Acceptable Long Term Exposure Range" ALTER is defined as that concentration range to which it is believed from existing information that a person may be exposed over a lifetime without undue risk to health. The intent here is to ensure that exposure levels averaged over a lifetime be within the specified ranges.

Carbon Dioxide and Water Vapour as an Indicator of Indoor Air Quality

Complaints of poor indoor air quality (headache, fatigue, unpleasant odours, stuffiness and warmth) have been linked with elevated concentrations of carbon dioxide. This substance can be useful as an indicator of general air quality in buildings where there are significant metabolic and/or combustion sources, and in several studies comfort factors have been correlated with carbon dioxide concentrations. Collectively, these studies indicate that carbon dioxide concentrations above 1,000 ppm (1,800 mg/m^3) are indicative of an inadequate supply of fresh air, although complaints have been cited as arising when levels of carbon dioxide are near 600 ppm.

These investigations have been done in buildings with ventilation systems and occupancy rates quite different from those of domestic premises, and it is likely that the effects observed might be attributable to the presence of other contaminants more common to buildings from inadequate ventilation. Therefore, caution must be used in interpreting carbon dioxide concentrations as a general indication of poor residential indoor air quality.

The Working Group reached a similar conclusion regarding relative humidity as a surrogate parameter. Extremes of humidity are primarily associated with sensations of discomfort or annoyance. Air-to-air heat exchangers, which are designed to bring in outside air and to turn on and off at preset relative humidity levels have been developed. The control of indoor air pollutants other than excessive water vapour by heat exchangers operating in this way may not be satisfactory for the following reasons:

- in a large house with a low occupancy, relative humidity may not rise sufficiently to trigger air exchange, although other pollutants may be present at unacceptable concentrations;

- changes in occupancy throughout the day affect the rate at which water vapour is generated, whereas other pollutants may be emitted continuously;
- the variation in indoor relative humidity with geographical area and season necessitates different control settings for each location and season. Therefore, relative humidity is not suitable as a general indicator of residential indoor air quality.

Example of the Derivation of a Guideline

Ozone

It was found that the concentration of photochemical oxidants in the home depends mostly upon the rate of infiltration of outdoor air. Levels were found to be highest when the windows were open. On average, concentrations indoors were found to range from 0 to 40 $\mu g/m^3$ (0 to 0.02 ppm), although peak levels of 200 to 400 $\mu g/m^3$ (0.1 to 0.2 ppm) have been measured.

Animal studies indicate that ozone can cause functional, biochemical, and structural changes in pulmonary and extrapulmonary systems, and that these changes exhibit dose-response relationships. Animal studies have also shown that exposure to ozone concentrations of about 200 $\mu g/m^3$ (0.1 ppm) impair respiratory function, and increase susceptibility to lung infections. An ozone concentration of 400 $\mu g/m^3$ (0.2 ppm) causes a reduction in lung elasticity, degenerative changes in cells lining the respiratory tract, and changes in the activity of the lung enzymes.

Human subjects previously exposed to ozone developed a tolerance or adaptation to concentrations below 800 $\mu g/m^3$ (0.4 ppm). It is not known if the development of adaptation is beneficial in the long term but it is thought that throughout this adaptation period, injury is occurring in the deeper lung tissue (3). Clinical studies show that significant increases in airway resistance begin at ozone concentrations of about 240 $\mu g/m^3$ (0.12 ppm). Increased activity and higher concentrations enhance this detrimental effect.

In epidemiological studies, headache, eye irritation, cough and chest discomfort were related to total oxidant levels in urban air. These effects were observed at ozone concentrations of approximately 240 $\mu g/m^3$ (0.12 ppm). Therefore, based on the results of available clinical and epidemiological studies, exposure to ozone indoors, for short periods (approximately 1 hour), should not exceed 240 $\mu g/m^3$ (0.12 ppm).

Indoor Air Quality Research - Past and Present - Environmental Health Directorate, Department of National Health and Welfare

The Directorate first became involved with indoor air quality research during the late

1970s as a result of specific concerns with potential health hazards associated with energy conservation in buildings. Initial investigations focused on the effects of energy conservation measures such as the retrofitting of urea-formaldehyde foam insulation (UFFI) and the use of wood as an alternative heating fuel. At about the same time, there was an increasing awareness of scientists, government officials, and the public that a variety of activities or materials may significantly contribute to indoor air quality problems. This prompted exploratory investigations on the effects of some commonly used consumer products, appliances for heating and cooking, and other factors which may affect IAQ. A conclusion from these initial studies was the lack of accurate information on human exposure levels to airborne contaminants. Consequently, a major component of the indoor air program which developed during the 1980's entailed development of procedures for measuring personal exposure to specific airborne pollutants. Recently, epidemiology and toxicology investigations have also been initiated to examine the health effects of selected airborne pollutants. Some examples of the studies conducted by the Directorate during the past 10 years are reported here.

In addition to advising other agencies on investigative projects, some research (4) on the occurrence and biological activity of airborne pollutants in UFFI insulated buildings was conducted by the Environmental Health Directorate. The analytical technology was also applied to investigations (5) on particulate matter in environmental tobacco smoke (ETS). The Directorate's program to discourage tobacco smoking by Canadians also has included an extensive effort to characterize ETS constituents and to determine their contribution to indoor pollution (6,7). Investigations on the effect of emissions from woodstoves on IAQ focused on the occurrence of airborne particles, and in particular on particle bound polycyclic aromatic hydrocarbons (PAH). The contribution of woodburning and cigarette smoking to indoor PAH levels was examined in several studies (8,9).

Development and evaluation of analytical methods for determination of airborne PAH has been a significant component of recent investigations. The finding (10) of deficiencies in methods for measurement of personal exposure prompted several studies on low-flow sampling methods (11,12,13) for PAHs and other aromatic species. Since knowledge of the distribution of organics between vapour and particulate phases is important in understanding the nature and extent of exposure, a dynamic test atmosphere generating system was designed and constructed (14). This system has been used to examine the behaviour of aerosols under various atmospheric conditions and to characterize sampling and chemical analysis methods. A passive sampling method for vapour phase PAH, amines and other aromatics is under development for personal exposure monitoring and has also been used for phase distribution studies. Experiments exploring the application of various chromatographic methods with mass spectrometric detection of high molecular weight PAH (ca. 300-1000 amu) are in progress.

The concern with potential exposure to volatile organic compounds (VOCs) initially led to examination of the effects on IAQ from the use of paint removers (15) and fabric protectors (16). Subsequently, the occurrence of VOCs in some offices (17) and residences (18) was surveyed. These studies demonstrated the need for more convenient and less expensive monitoring methods. An extensive program (19) to develop personal exposure monitors for volatile airborne organics at the $\mu g/m^3$ level was initiated. A successful outcome of this program was the characterization of a passive monitor for measurement of 26 VOCs. In conjunction with a custom designed GC-MS analysis procedure, the sampling method has been applied to investigations on factors affecting IAQ, small surveys of IAQ and a major pilot study (20) of the occurrence of the

26 VOCs in 760 randomly chosen Canadian homes. The monitoring phase for the latter study has just been completed and the final results should be available this year.

There is also a need to develop procedures for predicting exposures to organics under different building operating conditions and in the presence of the wide variety of pollutant sources which may be found indoors. Exploratory investigations on the feasibility of receptor and dispersion modeling of VOCs have also prompted development of source emissions and VOC occurrence data bases. Among other Canadian data, results from the 760 homes will be stored in the occurrence data base. A recent review article (21) explains the relationships between and provides useful information on sources, emissions, occurrence, analytical methods and the fate of indoor VOCs. The objective of current studies is to identify important target VOCs and their sources and to determine the effects of building characteristics on human exposure to VOCs.

In comparison to studies on organics, investigations by the Directorate on inorganic pollutants in indoor air have been relatively limited. Methods for personal monitoring of NO_x, SO_2, O_3 and particulate matter have been examined (22,23) and some monitoring and modelling experiments have been conducted. The occurrence of asbestos fibres and radon in indoor environments has been determined as a result of specific concerns by the public (24,25). Ozone and particulate matter have been monitored in schools and other locations to determine their potential effect on the health of children.

Although much more difficult to quantify than the physical and chemical characteristics, the potential health effects of some airborne pollutants have been investigated. An epidemiological survey of respiratory illnesses in children living in energy efficient homes in Saskatchewan was conducted. Also, monitoring methods for fungi and molds, which have been associated with human health effects, have been examined (26). Other investigations on indoor contaminants, e.g., bioaerosols, and their association with respiratory health of home occupants are in progress. Studies have already shown (27) that the respiratory health of children is affected by home dampness/mold. For example, in all of the following health indicators, there was a significant increase in reporting among children living in homes with dampness or visible mold: cough, wheeze, wheeze with dyspnea, asthma, bronchitis, chest illness, upper respiratory symptoms, eye irritation, nonrespiratory symptoms (at least one of: headaches, muscle aches, fever and chills, nausea, vomiting, or diarrhea, occurring on at least three separate occasions in the last 3 months). Similar results were shown among adults in this study (28). Adults were demonstrated to have adjusted odds ratios ranging from 1.45 to 1.63 in homes with dampness/mold as compared with homes with no such problems, for a range of symptoms including: upper respiratory symptoms, lower respiratory symptoms, chronic respiratory disease, asthma, and eye irritation. The mutagenic activity of several substances in the indoor environment has been examined (29,30,31). The toxicity of individual organics, e.g. furfural (32), benzaldehyde (33), and cyclohexanone, commonly found in indoor air is under investigation. The validation of 2 in vitro pulmonary toxicology methods, the lung slice method and the use of isolated pneumocyte cultures is also underway to examine the toxicity of air pollutants. The Directorate has a continuing program to examine the toxicology and pharmacokinetics of various substances which may be found in air or water.

Development of Further Guidelines

Plans to begin the process for updating the guidelines have been approved for the

1992/1993 fiscal year. An additional five parameters (xylenes, toluene, 1,4-dichlorobenzene, benzene, and tetrachloroethylene) will be considered for addition to the guidelines. If it is determined that it is possible to develop guidelines for these parameters, a request will be made to the Federal-Provincial Advisory Committee on Environmental and Occupational Health to consider re-establishing a Federal-Provincial Working Group to develop these further guidelines.

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