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FINDINGS OF THE ONTARIO INTER-MINISTERIAL COMMITTEE ON INDOOR AIR QUALITY

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INTRODUCTION

The Ontario Ministry of Labour (MOL) and Ministry of Government Services (MGS) have investigated more than 2000 indoor air complaints since 1976. All complaints were reported in sealed window buildings equipped with central heating, ventilating, and air-conditioning systems (HVAC). In many cases, the causes of the symptoms could not be found.

The concern about indoor air quality (IAQ) is shared by many ministries. It was recognized that IAQ complaints would likely persist in the future and that the Ontario government needs a guideline for defining indoor air parameters and a uniform protocol for investigating "sick building" complaints.

Within the Ontario government, the Inter-Ministerial Committee on Indoor Air Quality (henceforth called the committee) was established in 1987 to review "sick building syndrome." The Committee's mandate was to:

1. Define the terms related to indoor air quality (IAQ).
2. Review and evaluate health hazards related to IAQ.
3. Develop uniform protocol for investigating indoor air quality concerns and protocol for field measurements.
4. Recommend acceptable criteria for indoor air quality, including secondhand smoke exposure.

The committee's scope of investigation was also limited to commercial and institutional buildings. Residential and industrial buildings were excluded.

While review of the IAQ literature helped the committee to arrive at guidelines and recommendations made in this report, the protocol for investigating indoor air quality concerns, including the detailed questionnaire, was developed by the committee. *Our protocol is reactive rather than proactive.* The committee did not develop a recommendation for radon because another interministerial committee dealt with this issue.

The committee has prepared its report to guide government inspectors, occupational health professionals, and HVAC engineers in recognizing IAQ problems in nonresidential and nonindustrial buildings and in recommending remedial measures.

PROTOCOL FOR INDOOR AIR QUALITY INVESTIGATIONS

Flow Diagram

The flow diagram (Figure 1) shows the steps to be followed in the protocol for IAQ investigations. Such investigations are undertaken when complaints are received about the air in a building.

Stage 1—Preliminary Assessment

The preliminary assessment stage does not use instruments, but relies on an "inspection" and the "collection of information" on a building. The information comes from "observations" made in the building, knowledge of the operation of the HVAC system, and details of the complaints.

Two activities are involved in the preliminary assessment:

A. Collection of information about the building.
B. Interpretation of this information to provide evidence for or against the various causes of the problems.

For a complete inspection, the building checklist, given in Appendix A, should be used. Note that, whenever possible, ventilation systems should be "visually" checked to ensure that they are performing in a satisfactory manner.

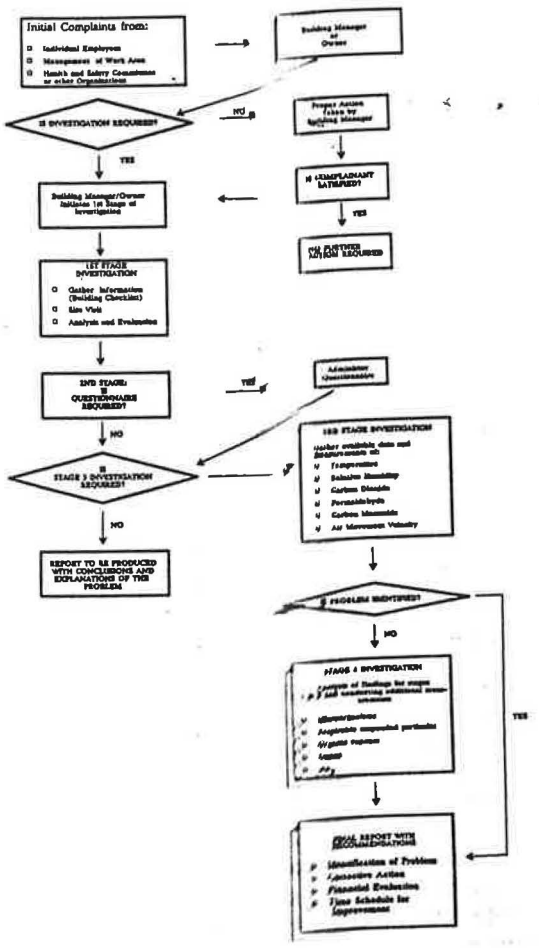

Figure 1 Protocol for IAQ investigation flow diagram

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The building checklist, divided into five parts, is as follows:

1. Carbon monoxide-combustion byproducts
2. Other pollutant sources
3. HVAC operations
4. Maintenance and design
5. Complaint area observation sheet.

Once information has been collected, the second activity in this stage is to interpret the results. Guidance on how to use the building checklist information to identify probable causes or problems is given in Part 6—Assessment Summary—of the building checklist.

The report from the preliminary assessment should include:

- Assessment of information collected.
- Recommendations for eliminating the problem.

If the cause of the problem is not identified, the questionnaire should then be administered.

Stage 2—Questionnaire and Analysis

A questionnaire has been developed as part of the protocol for IAQ investigation. The questionnaire is given in Appendix B.

The purpose of the questionnaire is to gather information on the types of problems that are experienced in the indoor environment. It has been designed to allow one to establish 1) whether and to what extent IAQ problems exist, and 2) what are the possible sources of contamination. Questions have been defined which provide an indication of exposure and the presence of the symptoms that are typically associated with each contaminant. The format and language of the questionnaire are simple so as to allow individuals to complete it without assistance.

Among the contaminants that can be assessed are: volatile organic compounds (VOC), carbon monoxide, ozone, particulates, microorganisms, and formaldehyde. Indicators of exposure to carbon dioxide, which itself is not regarded as a major contaminant, suggest the presence of ventilation problems. The questionnaire also allows assessment of the indicators of exposure and symptoms related to tobacco smoke.

The questionnaire also probes the incidence of common work environment complaints related to noise, lighting, humidity, temperature, air movement, etc.

Questionnaire Analysis

The analysis of the questionnaires for each IAQ investigation case is performed in three stages: (1) analysis of each questionnaire, (2) compilation of the results for all questionnaires, and (3) interpretation of the results.

For each contaminant, questions relating to symptoms indicate the presence of complaints typically associated with a contaminant (see Appendix C). The responses can be scored, and the higher the symptom's score, the greater the likelihood/severity that the symptoms are associated with the contaminant in question.

For each response, the presence of a symptom is scored by a value of "1." To simplify matters, it is assumed that each indicator of symptoms or exposure will have equal weighting (i.e., "1"). It is important to note that only symptoms that manifest themselves during regular working hours are of significance.

For each contaminant, exposure levels for individual responses are estimated in the same manner. High total exposure scores indicate a greater likelihood of exposure to the contaminant in question.

A series of worksheets has been developed to assist in the analysis of the questionnaire (Appendix C). A summary table for individual questionnaires will provide information about each contaminant and the severity of exposure (see Appendix D). Summary results of all questionnaires—for both symptoms and exposures—for different contaminants are compiled in a single table.

To compare scores for all individuals in an investigation, exposure and symptom scores can be plotted in the form of a frequency distribution chart (Appendix D). This chart provides information on the extent to which individual responses (relating to exposure and symptoms) vary among individuals in the survey. If high exposure and symptom scores are observed for only a small minority of individuals in the survey, the frequency distributions will reveal this.

Some indoor air problems are more severe at times in the day and/or week when the rate of fresh air distribution is lower and/or when contaminants have reached a higher concentration. A frequency distribution chart for days of the week may also assist in identifying the source of the problem.

The exposure and symptom scores can be compared for individual responses. High exposure and symptom scores may suggest that symptoms are indeed linked to the presence of a particular contaminant. If many of the responses in the survey exhibit the same pattern of high symptom scores associated with high exposure scores, then this would further suggest that there may be a widespread problem with a particular contaminant. A contingency table can be constructed and tests of significance can be performed (e.g., Chi Square) to determine whether or not there is a significant relationship between indicators of exposure and symptom intensity.

In the long term, analyses of different IAQ investigation cases may reveal trends, such as the relationship of IAQ problems to the sex of the respondents, type of office occupied, impact of other stress factors, etc.

Stage 3—Field Measurements with Simple Instruments

If the problem is not clearly identified following Stage 1 and if Stage 2 indicates a prevalence of certain symptoms or complaints, it is necessary to conduct Stage 3 of the investigation using simple instruments to take the following measurements:

- temperature
- relative humidity
- carbon dioxide
- formaldehyde
- carbon monoxide
- air movement.

It is important that the above measurements are taken in the proper location and at the appropriate time of year, week, and day. The tables in Appendix E indicate the suitable locations (including "control" locations) and time for measuring pollutants. Because the types of measurements made are unfamiliar to most people, the Data Assessment Table in Appendix F provides ranges of acceptable and unacceptable values for various pollutants. The measurement results can be compared against these ranges.

A list of simple pieces of equipment that are often used for measuring some basic pollutants is given in Appendix G. The measurements are easy to perform, and are designed to be used by non-specialists who have received a minimum of training (for example, a building operator, property manager, or safety officer).

It is expected that the data collected will prove or disprove the presence of hazardous levels of air pollutants in some cases, but not necessarily all cases. It may be necessary to go to Stage 4 to measure other potential pollutants that require complex measurement techniques.

Stage 4—Field Measurements with Complex Instruments

If the problem is not identified in Stage 3 and it is suspected that the air contamination is occurring from specific sources within or outside the building, and in the event that harmful chemicals, dust, or microorganisms are suspected, it may be necessary to do measurements of:

- microorganisms
- respirable suspended particulates
- organic vapor
- ozone
- NO_x
- asbestos.

These measurement techniques are more time-consuming and expensive to conduct than simple measurement techniques. They also require an expert to administer them. These measurements are usually only used after Stage 1, 2, and 3 evaluations have failed to resolve the situation.

Interpretation of Field Measurements

Stage 3 and 4 measurements should be compared with Appendix F of the report, which gives ranges of acceptable and unacceptable values for carbon dioxide, carbon monoxide, formaldehyde, nitrogen dioxide, ozone, and physical factors. The guideline levels for microorganisms are given in another section, "Guidelines for Indoor Air Quality," and can be used to make comparisons against measurements of microorganisms.

Several situations are possible:

- If all control and test location data fall in the normal outdoor and indoor ranges, any problems suspected are not due to this cause/pollutant.
- If control location measurements are in normal ranges and one or more test locations give numbers in the "do not exceed" range, this indicates that there are problems to be corrected.
- If control location data are in the normal range and one or more test locations give numbers in the "possible problem" range, more detailed testing may be necessary.
- If test and control locations give numbers in the "possible problem" range, the problem could lie with the outdoor air or with the equipment.

SOURCES OF CONTAMINANTS

Many contaminants have been isolated from indoor air. They can be grouped under two broad headings:

(1) those that originate from "internal" sources; and
(2) those that have their origin "outdoors."

Internal sources were classified as building components, the HVAC (heating, ventilating, and air-conditioning) system, people, furniture, office supplies and equipment, and parking garages. External sources were defined as ambient air infiltration. Common for both sources are temperature, humidity, carbon dioxide, carbon monoxide, formaldehyde, microorganisms, organic solvents, and odor. Noise, radiation, asbestos, and ergonomic and working conditions are excluded from these groups.

LIST OF OFFICES AND BUILDINGS

In developing this list (Table 1-Appendix H), only those buildings that have extended occupancy, such as places where people are present all day, are considered as opposed to intermittent occupancy, such as underground concourses. Places with intermittent occupancy were excluded because they cannot be properly evaluated using our protocol.

GUIDELINES FOR INDOOR AIR AND BUILDINGS

Factors Affecting Indoor Air Quality

The quality of indoor air in an office or public building is determined mainly by the quality of outdoor air provided, by the presence and strength of emissions from indoor sources, and by the extent of air exchange—natural or mechanically assisted—between the indoors and the outdoors. Minor influences are the reactions of chemicals and their uptake and release by surfaces.

Air pollutants generated indoors result from "human presence and activities" and fall into four main categories:

- those related to "human activity," including biological agents, products of human metabolic activity, and inorganic and organic chemicals, including personal care products used in the performance of various tasks;
- those formed by "combustion processes," including tobacco smoke;
- those given off by the "heating, ventilating, and air-conditioning equipment" and products used in their maintenance, including biological agents (bacteria, fungi, and other microorganisms and allergens); and
- those given off by the "construction materials, finishes, and furnishings" used in the building.

The concentrations of contaminants in the first three categories vary with the amount of human activity. Those in the fourth category are likely to be more constant but will decrease slowly with time, over a period of months or years, after the installation of furnishings and the construction or modification of the building.

The major causes or types of IAQ problems are: 1) inadequate ventilation (50% to 70% of cases investigated), 2) contamination from inside the building, 3) contamination from outside the building, 4) microbiological contamination, and 5) contamination from the building fabric (NIOSH 1988; Collett and Sterling 1988).

A summary of indoor pollutants, emission sources, and concentrations is shown in Table 2 (Spengler and Sexton 1983) and in Figure 2 (Nero 1988) of Appendix H. Indoor concentrations are usually higher than the outdoor concentrations because indoor sources are emitted to a confined volume of air with smaller dilution. For example, the U.S. EPA team study (Wallace 1987) found that personal air exposures for 11 volatile chlorinated and unchlorinated hydrocarbons were greater than outdoor exposures. The major reason appeared to be elevated indoor air levels at work and at home. Also, the considerable variability in the concentrations of several chemicals was caused by widely varying emission rates.

Special mention should be made of tobacco smoke. Nearly everyone is exposed at one time or another to it. This includes not only the smokers themselves, but also those who inhale the so-called sidestream smoke of others. There is increasing evidence that passive exposure to tobacco smoke may affect human health. The effects range from short-term irritation of the eyes, nose, and throat (as well as other discomfort, such as headache), to aggravation of the conditions

of people with pre-existing disease, including heart disease, lung disease, and allergies to other substances, and to cancer, chiefly of the lungs but also of other organs (Glantz 1984). The International Agency for Research on Cancer (IARC 1986) has concluded that direct inhalation of tobacco smoke is carcinogenic to both humans and animals and that passive smoking gives rise to some risk of cancer.

Tobacco smoke contributes to increased air concentrations of respirable particles, nicotine, polycyclic aromatic hydrocarbons, carbon monoxide, acrolein, nitrous oxide, and numerous other substances. Many of the components are established or suspected carcinogens, irritants, and asphyxiants. The range of concentrations found in a building is very wide and depends on the frequency and amount of smoking, air infiltration rates, air-cleaning devices, and air distribution systems (Glantz 1984).

Existing Standards and Guidelines

The symptoms and complaints associated with IAQ problems are generally nonspecific and difficult to monitor and evaluate objectively. The symptoms include eye, nose, and throat irritation; inflammation, mental fatigue, and headaches; unspecified hypersensitivity reactions and respiratory diseases such as allergic rhinitis, asthma, and hypersensitivity pneumonitis; and complaints about taste and odor. Generally, the causes are multi-factorial and it has not, in general, been possible to identify the agents and human factors responsible. Therefore, it has been difficult to develop exposure guidelines to chemical and biological agents in the nonindustrial workplace to protect workers.

Two groups have developed IAQ guidelines: the World Health Organization (WHO) and the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). Their approaches exemplify the two possibilities for controlling indoor air quality: 1) set permissible levels for air pollutants, or 2) set minimum ventilation standards, which are intended to dilute pollutants to an acceptable level.

Existing standards and guidelines are discussed as follows under the headings of the main causes mentioned above: ventilation, indoor contamination, outdoor contamination, microbiological contamination, and contamination from the building fabric. Certain of these standards/guidelines are proposed for use in nonindustrial and nonresidential buildings.

Ventilation

ASHRAE produces ventilation standards that are used in most North American nonindustrial buildings. The standards, which are in the process of being updated, provide heating, ventilating, and air-conditioning (HVAC) engineers with two approaches for achieving acceptable ventilation levels in buildings. They are:

- ensuring that there is a prescribed minimum supply of acceptable outdoor air on a per-person and/or a per-space basis; or
- ensuring that an amount of outdoor air is supplied that will maintain indoor air pollutants below specified levels.

ASHRAE Standard 62-1981 (ASHRAE 1981) currently prescribes 5 cfm/person (2.5 L/s/person) of outdoor air for non-smoking offices. In offices where smoking is permitted, 20 cfm/person (10 L/s/person) is required. In addition, Standard 62-1981 introduced an alternative air quality procedure allowing any amount of outdoor air to be used provided that indoor air pollutants are below acceptable limits.

In 1986, a new ASHRAE standard—62-1981R (yet to be adopted)—was proposed because of new information of complaint frequencies relative to carbon dioxide levels in buildings of various occupancies and on percentage dissatisfaction with human bioeffluents, such as found in chamber studies. This standard proposes a minimum of 15 cfm/person (7.5 L/s/person) of outdoor air in any setting, with a minimum of 20 cfm/person for offices to allow for some additional air pollution such as from office equipment and a small amount of smoking. The air quality criteria to be used as alternatives to using the minimum prescribed outdoor air supply are given in Table 3-Appendix H.

The carbon dioxide limit is recommended as a surrogate measure for the lack of fresh air supply and odor levels; that is, if CO_2 is below this value, enough fresh air is supplied to dilute the pollutants (ASHRAE 1986).

The Ontario Ministry of Labour (MOL) has determined from its IAQ investigations that carbon dioxide levels can be related to the frequency of occupant complaints. The MOL's findings are given in Table 4-Appendix H, together with the equivalent air supply (Rajhans 1985). The MOL has proposed a guideline of 1000 ppm CO_2 to indicate that fresh air supply is insufficient. Carbon dioxide levels can also be used to indicate effective ventilation rates in buildings, and the calculation to do so is given in Table 5-Appendix H.

Table 1-Appendix H lists outdoor air requirements for various types of buildings. The buildings were selected by the Committee as those most likely to encounter IAQ problems. The table is also based on the occupancy classification of the Ontario Building Code.

Indoor Contamination

Offices, schools, retail spaces, and similar buildings cannot be considered as equivalent to industrial workplaces. As ASHRAE (1986) points out, the level of discomfort and irritation that is acceptable for workplaces and occupational

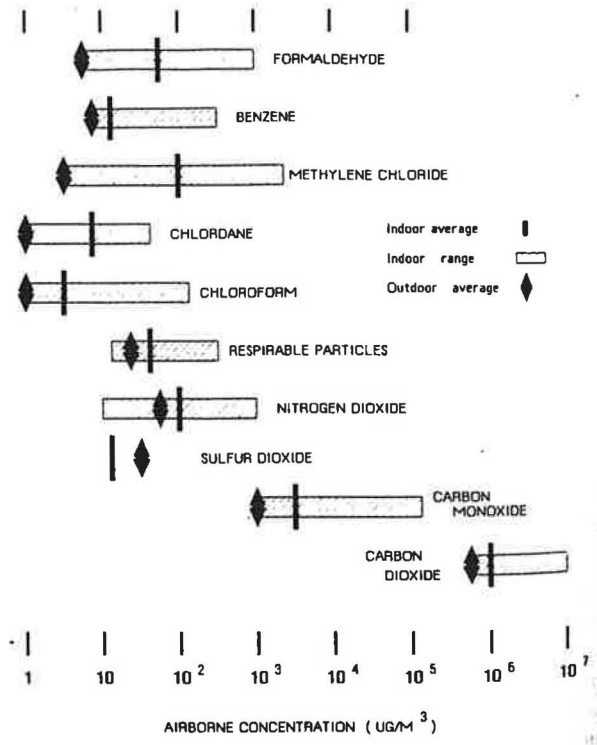

Figure 2 Indoor and outdoor air concentrations of selected pollutants (Source: Nero 1988)

exposures where chemicals are routinely used would be unacceptable for residential, office, or retail spaces. Therefore, occupational standards—for example, the threshold limit values proposed by ACGIH—are not relevant measures of IAQ in nonindustrial settings.

Canada's Federal/Provincial Advisory Committee on Environmental and Occupational Health also rejected the use of occupational limits for setting indoor air quality levels in nonindustrial buildings (HWC 1987).

ASHRAE (1986) points out that, as a preliminary guideline for nonindustrial indoor spaces, it was customary advice to assume that a concentration of 1/10 of the occupational standards would not produce complaints. However, these levels may not provide adequate protection to individuals who are very sensitive to some irritants, such as formaldehyde. The occupational standards and guidelines for some chemicals of interest in indoor air pollution are given in Table 6-Appendix H.

The World Health Organization (WHO) has also been active in this field. A Working Group of WHO has developed IAQ guidelines (WHO 1984) which are given in Table 7-Appendix H.

The guidelines developed for residential buildings by a Working Group of the Federal/Provincial Advisory Committee on Environmental and Occupational Health were released in 1987 (HWC 1987). These guidelines can be applied to nonindustrial workplaces. The reasons for applying these guidelines are that:

- all aspects of indoor air, including pollution sources and how guidelines and recommendations should be derived, were examined in the report;
- available information and guidelines from other jurisdictions were examined for their application to Canadian conditions;
- the Working Group has prepared comprehensive documentation, as yet unpublished, which gives the scientific basis for its recommendations;
- although the guidelines were not developed for other environments, such as industrial workplaces where other factors may be important (Armstrong et al. 1985), the guidelines are relevant for offices. Office environments differ little physically from residences and also contain similar construction materials, finishes, and furnishings. Both environments may also have occupants who are similarly at high risk to contaminant exposures.

The residential guidelines were developed to protect a person's health over a lifetime, "taking into account such factors as the sensitivity of groups at special risk and the sources and mechanisms of action of contaminants." Ideally one would want to develop guidelines that would protect a person at work, at home, and in the outside environment. The residential guidelines can logically include the office in addition to the home environment, and thus come close to providing this ideal.

These exposure guidelines are summarized in Table 8-Appendix H.

A comparison of the exposure ranges in Table 8 and the WHO (Table 7-Appendix H) and ASHRAE numbers (Table 3-Appendix H) is not entirely valid since the exposure times are different. Nevertheless, the concentrations in the three tables are quite close.

For substances without a specific exposure guideline, the Working Group made the following recommendations for controlling exposure:

1. Consumer products

   "It is recommended that exposures resulting from the use of consumer products be kept at a minimum by ensuring adequate ventilation and observing any other precautionary measures described on the product label and any accompanying information. Pest control products should be used only when absolutely necessary."

   In addition to pest control products, the Working Group specifically mentioned chlorinated hydrocarbons, which are used principally as solvents, cleansers, and aerosol propellants. In some cases, these may be released continuously from consumer products. The Group also mentioned that product aerosols may contain hazardous substances, both in the propellant and as the active ingredient.
2. Fibrous materials

   "Precautions should be taken to minimize inhalation of, and skin contact with, mineral fibres. Materials and products containing fibres should also be examined periodically for signs of deterioration. Advice should be sought before removing or damaging any materials thought to contain asbestos."

   The Working Group specifically mentioned asbestos and man-made mineral fibers such as fiberglass, mineral wool, and ceramic fibers. Such substances can cause transient irritation of the skin and eyes. Asbestos can cause mesothelioma, a specific form of cancer, upon prolonged exposure.
3. Lead

   "In order to minimize exposure of people . . . to lead of airborne origin, it is recommended that surfaces that may be contaminated be cleaned frequently and that a high standard of overall cleanliness be maintained."
4. Polycyclic aromatic hydrocarbons

   Exposure to these substances indoors should be kept to a minimum by ensuring that combustion systems "are properly installed and maintained and operated under conditions of satisfactory ventilation" and that the Working Group's guidelines and recommendations for particulate matter and tobacco smoke be adhered to.
5. Tobacco smoke

   "In view of the carcinogenic properties of tobacco smoke, it is recommended that any exposure to tobacco smoke in indoor environments be avoided."

Outdoor Contamination

Assuming adequate ventilation and no indoor sources of contaminants, the indoor air quality will be approximately the same as that outdoors. It cannot be assumed, however, that indoor air concentrations are necessarily the same as the ambient outdoors, since localized sources, such as garages, chimneys, and other vents may—depending on the location of the HVAC—give rise to elevated concentrations.

Table 9-Appendix H lists air quality or ambient air guidelines from some jurisdictions. These guidelines may not be relevant to shorter and higher exposures to contaminants in indoor air.

Biological Contamination

Bioaerosols include viable microorganisms (bacteria, fungi, algae, mites, viruses) and nonviable biological matter (plant pollens, animal danders, insect fragments, etc.). The microorganisms living in HVAC systems are generally saprophytic; that is, they obtain nourishment from dead organic matter and proliferate on surfaces that are wet and often dark.

Excluding infectious diseases, bioaerosols can cause allergic reactions on the skin (contact dermatitis, hyperreactivity) or in the respiratory tract (allergic rhinitis, asthma, hypersensitivity pneumonitis, pulmonary eosinophila).

The Health and Safety Support Services Branch of the MOL recommends adoption of the following guidelines as indicators of the need for improving conditions in the HVAC system:

- levels of bacteria within the HVAC system in excess of 1 x 10^5 colony-forming units (CFU)/mL in stagnant water or slime.
- levels of fungi in excess of 1 x 10^6 CFU/g in HVAC system dust.

The Federal/Provincial Working Group on Residential Air Quality (HWC 1987) has recommended the following approach for controlling biological contamination:

"In order to prevent many of the common indoor problems due to biological agents, measures should be taken to ensure that:

- excess humidity and condensation are not present,
- surfaces are kept free of dust,
- stagnant water sources such as humidifier tanks are kept clean and occasionally disinfected, and
- a high standard of appropriate personal hygiene is maintained."

Contamination from Building Materials and Products

Products such as adhesives, paints, and sealants contain solvents and other agents that can be released during and immediately after application. Organic contaminants can also be released from building materials over long time periods. One of the more notorious is formaldehyde, which emanates from chipboard, panel adhesive, carpet backing, vinyl wall covering, resin-treated fabrics, and insulation (NRC 1981).

Emissions of organics from 42 commonly used building materials have been measured and more than 50 compounds were identified. About two-thirds were aliphatic or aromatic hydrocarbons, with the remainder being ketones, alcohols, esters, aldehydes, and halogenated alkanes. Some of these compounds are suspected irritants and carcinogens. Because emission rates decrease greatly as a building ages, contamination from the building fabric is likely to be a problem mainly in new buildings (Wilfert et al. 1986).

Assuming that chemical release rates are not too high, then the ventilation and air quality guidelines outlined in this section are applicable. However, if the concentrations rise above the air quality guidelines despite the ventilation standards being met, then it may be necessary to adopt other measures, such as 1) allowing new buildings to "de-gas" until acceptable concentrations are reached, 2) using materials with low chemical release rates, 3) testing and labeling products as to their releases, or 4) isolating such products if used. However, the implementation of such measures will require considerable research as well as the setting of regulations by governments.

Recommended Guidelines for Indoor Air Quality in Non-Industrial Buildings

There are three stages to achieving acceptable air quality in offices, schools, and similar nonindustrial buildings, assuming that the make-up air is of satisfactory quality:

1. The ventilation rate per person should be higher than 7 L/s (15 cfm). This ventilation rate is equivalent to 1000 ppm CO_2

   (Tables 4 and 5-Appendix H).
2. (a) If this does not result in satisfactory air quality, then steps should be taken to meet the indoor air quality guidelines in Table 8-Appendix H. Although some jurisdictions may have lower levels, the guidelines in Table 8 have been derived after a comprehensive review of the existing knowledge about the compounds.

   (b) The qualitative guidelines in Table 10-Appendix H can also be used, although some of the health effects would only be manifested after months or years.
3. If satisfactory air quality still cannot be met, then consideration should be given to seeing whether the WHO guidelines are met (Table 7-Appendix H).

There are two objectives in the setting of standards or guidelines for indoor air quality. One objective is to control the exposure of the entire population, including susceptible groups such as those with pre-existing health conditions. Another is to avoid extreme levels, thereby limiting individual risk of disease, fatal or otherwise. The objectives can be achieved by formulating standards or guidelines that either control the factors affecting pollutant concentrations (e.g., ventilation) or by establishing concentration limits for pollutants without specifying the means by which these limits can be reached. The concentration limits for indoor pollutants as set out are probably more effective at avoiding excessive individual exposures than at controlling the average exposure of a population.

Nevertheless, the average exposure to indoor pollutants can gradually be lowered as a long-term goal. This can be achieved by establishing standards or guidelines that regulate the factors affecting indoor pollutant concentrations. For this reason, it is important to identify how source, ventilation, and structural characteristics affect indoor air quality.

The control of indoor air pollutants can be achieved through measures such as 1) prescriptions for air ventilation exchange rates and product standards for construction materials and furnishings, 2) restrictions on the use of potentially hazardous materials in products used in offices, 3) certification programs for builders and other trades, and 4) distribution of public information or a combination of all of these. Spengler and Sexton (1983) give further examples of control measures for air pollutants (Table 11-Appendix H).

The guidelines for indoor air quality presented in this paper can provide a reference point for assessing the extent to which such remedial measures need to be taken. The precise manner in applying and implementing these guidelines will have to be determined through further discussions with those groups whose activities and responsibilities encompass these areas (Wylie and Armstrong 1986).

The Committee did not find any IAQ standards established for children in schools. It has been reported that factors related to younger age groups include a higher respiration rate per unit body weight and less ability to comprehend and communicate adverse health effects. Another factor to be considered is aggravation of pre-existing disease in children. The guidelines proposed here appear to be stringent enough to protect the health of adult office workers as well as school children, hence the recommendation for its adoption.

SECONDHAND SMOKE EXPOSURE

Cigarette smoke is a complex mixture of several hundred substances: irritants (aldehydes), toxic chemicals (carbon

monoxide), and carcinogens (benzo (a) pyrenes, tars, etc.). More than 50 of these are known to cause adverse health effects: 12 are known or suspected carcinogens.

In the office environment, the primary complaint is one of irritation to the eyes and upper respiratory tract, usually caused by the aldehydes present. Unfortunately, it is difficult to ascertain an individual's exposure to irritants by means of an ambient air measurement alone. Irritating aldehydes disperse in the room air so that their total concentration is low—much lower than reported irritant levels. However, measurements taken directly in the breathing zone of the exposed person can show levels several hundred times the irritant concentration (Ayer 1983).

Of more concern, however, are the findings of studies that suggest an increased risk of lung cancer in non-smokers exposed to cigarette smoke (Hirayama 1981). In addition, certain epidemiological studies have pointed to an increase in respiratory illness in children exposed to secondhand cigarette smoke (House 1985). Other health effects in non-smokers include headache, nausea, dizziness, loss of appetite, aggravation of asthma, or angina.

It has been estimated that 63% of non-smokers are exposed to tobacco smoke at work and 86% of non-smokers either at home, at work, or both. The ambient concentrations of secondhand smoke are much lower than the concentration to which active smokers are exposed. Thus, it has been calculated that, in an office where many people smoke, secondhand exposure is equivalent to one to five cigarettes per day (House 1985). Statistical analyses have been conducted to predict that approximately 5000 persons in the U.S. die annually from lung cancer caused by exposure to secondhand cigarette smoke (Repace 1982).

To date, no one satisfactory method is available to measure the amount of cigarette smoke present in a workplace. Concentrations of carbon monoxide are sometimes used as an indicator of irritation complaints. Other more specific pollutants (such as nicotine and formaldehyde) are present in such low concentrations in ambient air that they cannot be used as practical indicators. Other components present in larger concentrations have many sources besides cigarette smoke, e.g., carbon dioxide is a human metabolite and particulates can arise from paper, furnishings, clothing, etc.

Building inhabitants should be encouraged to adopt a non-smoking policy, both in view of the health implications for non-smokers and the fact that smoking is the largest preventable cause of death in Canada. This has been done for many Ontario Ministries and municipal by-laws have been enacted to this effect, e.g., Toronto (Hauser 1984). Designated non-smoking areas, without a separate ventilation system, are not effective in restricting exposure to secondhand smoke. Separate ventilation systems for smoking areas have been recommended, but retrofitting an existing workplace with separate ventilation systems is often economically impractical (Hauser 1984).

CONCLUSIONS

Adoption of uniform definitions of indoor air quality (IAQ) terminologies and a uniform protocol of IAQ investigations is recommended. Details are given in the report (Province of Ontario 1988). Part of the recommended protocol is a comprehensive questionnaire and its analysis.

Because the sources of indoor pollutants cannot be avoided in most cases, the Committee proposes that adequate fresh air supply is the single most effective solution to IAQ problems, provided that heating, ventilating, and air-conditioning (HVAC) systems are properly designed, operated, and maintained. For buildings without a complete mechanical ventilation system, full advantage should be taken of the ventilation provided by openable windows.

The guidelines presented in this paper for IAQ provide reference points for assessing the extent of remedial measure in buildings.

The Committee was unable to find any regulatory standards for IAQ specifically established for children in schools. However, the guidelines proposed in this paper are stringent enough to protect the health of school children. The guidelines in Table 8-Appendix H were developed by taking into account high-risk groups such as the very young and elderly.

The Committee recommends adoption of a non-smoking policy by Ontario Ministries due to the presence of several known or probable carcinogens as well as other toxins in "mainstream" and "sidestream" smoke. Until such time as the non-smoking policy is adopted, buildings should be provided with designated smoking areas with a separate exhaust and ventilation system.

The Committee recommends that appropriate changes be made to the Ontario Building Code to reflect the findings of this report.

ACKNOWLEDGMENTS

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APPENDIX A

BUILDING CHECKLIST
(SOURCE: Public Works Canada. Indoor Air Quality Test Kit: User Manual, 1988.)

PART 1: CARBON MONOXIDE — COMBUSTION BY-PRODUCTS

Possible sources of carbon monoxide and combustion by-products in the building are identified below. Go down the numbered list of sources. Indicate whether or not this building does contain each (choose YES / NO by underscoring, circling etc.). If the answer is "NO," go to the next numbered question. If the answer is "YES," answer the rest of the questions in the paragraph (which all concern this source) before going to the next numbered question.

1) Does the building contain an *internal parking garage?* YES / NO
   Is the garage enclosed with a ventilation system? Yes / No
   If so, is the ventilation system controlled by carbon monoxide sensors? Yes / No
   Is it more than six months since the carbon monoxide sensors were recalibrated? Yes / No
   Are there any obstructions in the exhaust or fresh air? Yes / No
   Is the garage full for most of the day? Yes / No
   Are there cars coming and going for most of the day? Yes / No
   Does the checkout booth lack its own ventilation? Yes / No

2) Does the building contain an *internal loading dock?* YES / NO
   Is there an outer door which is closed after a truck's arrival? Yes / No
   Do the drivers keep their motors running in the dock? Yes / No
   Are there usually more than ten deliveries each day? Yes / No
   Are doors to other parts of the building kept open? Yes / No
   Is the reception office open to the loading dock? Yes / No
   Does the reception office lack its own ventilation? Yes / No

3) Does the building contain *a kitchen with gas stove(s)?* YES / NO
   Are the exhaust hoods above the stoves missing or faulty? Yes / No
   Are the stoves often operated without the exhausts switched on? Yes / No

4) Does the building contain a *gas-fired heating system?* YES / NO
   Are there any signs of leaks in the furnace or chimney? Yes / No
   Is the chimney vented into the building ventilation system rather than direct to outdoors? Yes / No

5) Does the building contain any *small free-standing gas heaters?* YES / NO
   Is there a smell of gas or burning around the heaters? Yes / No
   Is the exhaust vented into the building ventilation system rather than direct to outdoors? Yes / No

PART 2: OTHER POLLUTANT SOURCE

Possible sources of volatile organic compounds (VOC), formaldehyde, and biological material in the building are covered in this part of the checklist. As before, indicate whether or not this building does contain each potential source by answering the numbered questions. If the answer is "NO," go to the next numbered question directly. If the answer is "YES," answer the rest of the questions in the paragraph before moving on.

6) Are there *shower facilities* in the building? YES / NO
   Are these facilities used more than ten hours a week? Yes / No
   Is there any mold visible on the floor or walls of the shower stalls, the shower heads or shower curtains? Yes / No
   Are there moldy odours in the shower stalls or nearby? Yes / No

7) Does the building contain *wet-process photocopiers?* YES / NO
   Are any of these machines in small rooms with no air supply or exhaust? Yes / No

   If *yes* give the locations of these machines.

   _____ _____ _____

8) Does the building contain a *printshop?* YES / NO
   Are solvents regularly used to clean the equipment? Yes / No
   Are the waste rags or paper used during cleaning disposed of in an open garbage can? Yes / No
   Are any of the bottles or cans of chemicals Yes / No

usually left open or with the lids loose?
Do any of the machines lack an exhaust hood? Yes / No

9) Does the building contain a *laboratory which uses chemicals (for cleaning, processing, conservation, etc.)?* YES / NO
Are volatile chemicals used frequently? Yes / No
Are these volatile chemicals used without the protection of fume hoods? Yes / No
Is there a persistent odour in the laboratory area? Yes / No
Does the laboratory use the same ventilation system as the rest of that area of the building? Yes / No

10) Does the building contain *stored chemicals* (pesticides, waste solvents, etc.)? YES / NO
Do any of the chemicals stored evaporate quickly? Yes / No
Are any of the bottles or cans left open or with the lids loose? Yes / No
Is there a persistent odour in the storage area? Yes / No
Is the storage area unventilated? Yes / No

11) Does the building contain a storeroom or storage area with *shelves made of plywood or particleboard?* YES / NO
Is the plywood or particleboard used as bought, without a coat of paint or varnish? Yes / No
Is the storage area unventilated? Yes / No
Is there a persistent odour in the storage area? Yes / No

12) Is there a ban on smoking in this building? YES / NO
Is the ban only partial, with special smoking rooms allowed? Yes / No
If *Yes*, give locations of these rooms:

_____ _____ _____

Do any of these lack both a window fan and an electrical air cleaner?

Yes / No Yes / No Yes / No

Do any of these have a fan or window fan that blows the smoky air out through the door?

Yes / No Yes / No Yes / No

13) Are large amounts of *paper* stored in the building? YES / NO
If *YES*, give the location:

_____

Does frequent movement of paper take place? Yes / No
Is there dust on surfaces in this area? Yes / No

PART 3: HVAC OPERATION

As before, if the answer to a numbered question is "YES," answer the rest of the questions in that paragraph (if any). Otherwise, go to the next numbered question.

If the building contains two or more towers or wings which are essentially separate, and are controlled by different HVAC systems, a copy of this sheet should be filled out for each.

14) Is the *amount of fresh air* used by the ventilation system the same all year round? YES / NO
What is the percentage fresh air used? _____

15) Is the building run on an *economizer cycle?* YES / NO
What is the maximum percentage of fresh air used? _____
What is the minimum percentage of fresh air used? _____
What is the fresh air percentage just now? _____

16) Is *air* supplied to the floors by:
constant volume boxes / VAV boxes / heat pumps?

17) At what temperature is the tank supplying *hot water* to the building maintained? _____

18) Does the building contain *fresh air intakes?* YES / NO
Are the intakes below third floor level *and* above a busy street? Yes / No
Are the intakes above the entrance to a loading dock? Yes / No
Are the intakes above the entrance or exit to a parking garage? Yes / No
Are there any other pollution sources near the intakes? Yes / No
If *Yes*, describe them:

_____

Are there obstructions (i.e. birds' nests) lodged in the air intake? Yes / No
Are the intakes within 10 meters (30 feet) of the exhausts of this or an adjacent building? Yes / No

19) Is the *ventilation in the work areas* decreased or shut off overnight or at weekends? Yes / No
If *decreased*, the system goes down overnight to _____% of daytime.
Shut-off/decrease hours are from _____pm to _____am

20) Does this building have *a particulate (dust) filter* system installed in the fresh air intake? YES / NO
Are the filters changed less frequently than recommended by the manufacturer? Yes / No
Does the filter fit so poorly that air bypasses it at the edges? Yes / No
Are the filters matted or dirty? Yes / No

21) Are *spray humidifiers* used in this building? YES / NO
Are they operating today? Yes / No
Are the pans drained less often than once a week? Yes / No
Is there slime in the humidifier pans? Yes / No
Are there moldy odours? Yes / No
Is there mold on the ducts on the building side of the humidifiers? Yes / No
Is the water hard in this region? Yes / No
If so, are there hard water deposits on the vanes? Yes / No
Are the hard water deposits removed by scraping the vanes and blowing the dust into the ducts? Yes / No

22) Are *steam humidifiers* used in this building? YES / NO
Are they operating today? Yes / No
Are volatile chemicals used in the boiler or the pipes to prevent corrosion? Yes / No
If *Yes*, names of chemicals are:

_____

23) Does this building have an *air-conditioning system?* YES / NO
Is the system operating today? Yes / No
Are the condensate trays cleaned less often than once a week? Yes / No

Is there slime on the condensate trays? Yes / No
Is there slime on the cooling coils? Yes / No
Are there moldy odours in the system? Yes / No

24) Are the ventilation ducts or plenums *insulated?* YES / NO
Is the insulation on the inside? Yes / No
Is it more than five years since the ducts or plenums were last cleaned? Yes / No

PART 4: MAINTENANCE AND DESIGN

As before, if the answer to a numbered question is "YES," answer the rest of the questions in that paragraph (if any). Otherwise go to the next numbered question.

25) What year was the building constructed? _____
Was the building commissioned after occupancy? Yes / No

26) Can the *windows in the work areas be opened?* YES / NO
Do the occupants frequently open the windows? Yes / No

27) Have any *open office spaces been converted to closed offices* since the building was opened? YES / NO
If *YES*, give location:

_____

Was the original ventilation retained in this area? Yes / No
Do most of the closed offices lack thermostats? Yes / No

28) Have structural alterations resulted in *increased occupant density* anywhere in the building? YES / NO
(i.e. conversion of office space to boardrooms or waiting rooms)
If *YES*, give location:

_____

Was the original ventilation retained in this area? Yes / No
Does this space lack a thermostat? Yes / No
Is this space used for more than two hours each day, or ten hours a week? Yes / No
What is the peak occupant density?
_____ people in _____ sq. feet

29) Are any work areas being *recarpeted* just now? Yes / No
If *YES*, give the location:

_____

Do odours persist for more than a week after the carpet has been laid? Yes / No

30) Are any work areas being *repainted* just now? YES / NO
If *YES*, give the location:

_____

Do odours persist for more than a week after the paint has been applied? Yes / No

31) Is there *foam insulation* in the walls of the building? YES / NO
Is it Urea Formaldehyde Foam Insulation? Yes / No / do not know

PART 5:
COMPLAINT AREA OBSERVATION SHEET

no._____

Floor: _____ Room/Workstation:_____

All the questions should be answered. Where a choice of answers is given, please circle or underscore the most appropriate.

1) *General Observations* Yes / No
Are there damp patches or mold on the wall or ceiling?
Are there a lot of potted plants in this area? Yes / No
Is there mold on the plants or their pots or soil? Yes / No
Are there odours here? Yes / No
If *Yes*, describe the odours:

_____

Are people using fans to make more air movement? Yes / No
Is there a lot of dust visible on flat surfaces? Yes / No

2) Is this room an *enclosed office* (with walls and door)? Yes / No
If *Yes*, is it missing a thermostat? Yes / No

3) Is this an *open office* area? Yes / No
If *No*, go to question 4.
Are screens used to divide the area up? Yes / No
If *No*, go to question 4.
Are the screens more than five feet high? Yes / No
What is the average area enclosed by the screens? _____sq. ft.

4) Check the *air supply diffusers.*
Does this room lack supply air? Yes / No
Can you see any of the following on or around the diffusers?
mold / chalky dust / dirt marks
Are any of the diffusers blocked by furniture, papers or any other obstruction? Yes / No

5) Check the *air exhaust louvers.*
Does this room lack exhaust? Yes / No
Are there dirt marks on or around the louvres? Yes / No
Are any of the louvers blocked by furniture, papers or any other obstruction? Yes / No

6) Are any of the following *pollutant sources* within 30 feet (10 metres) of this room/workstation:
wet-process photocopier? Yes / No
printshop? Yes / No
room where chemicals are used? Yes / No
room where chemicals are stored? Yes / No
area with plywood/particleboard shelves? Yes / No
smoking room? Yes / No
an area with a lot of stored paper? Yes / No

Comments:

PART 6: ASSESSMENT SUMMARY

Three things are needed before an air quality problem needs further investigation using simple instruments. You can remember them as *PIP*, *P*eople, *I*nadequate ventilation and *P*ollutants. The presence of people is important, and problems can sometimes be tolerated in unoccupied areas such as basement mechanical rooms. Ventilation which is adequate in one situation, such as a large office, may be inadequate in

another, such as a printshop. It all depends on the balance between the capacity of the ventilation system and the strength of the pollutant sources.

An assessment procedure is described below for each of the parts of the Checklist questionnaire. Most of the questions have been worded so that a "Yes" answer means a possible problem. The simplest assessment procedure just consists of counting the number of "Yes" answers. Sometimes it is necessary to refer to the answers of other questions to obtain an effective assessment.

Part 1: Carbon monoxide/combustion byproducts

The numbered questions each refer to a possible source of carbon monoxide/combustion products in the building. For each of these that the building contains (a "Yes" answer), problems are *only* likely if one or more "Yes" answers are obtained to the other questions in the same paragraph. The more "Yes" answers, the more chance of a problem.

Part 2: Other Pollutants

The numbered questions each refer to a possible pollutant source in the building. For each of these that the building contains (a "Yes" answer), problems are *only* likely in practice if "Yes" answers are obtained for other questions in the same paragraph. The more "Yes" answers, the more chance that this pollutant source will be causing problems. The pollutant sources that the numbered questions refer to are:

6) fungi if mold visible anywhere, or moldy odours present
7) volatile organic compounds (VOC)
8) VOC
9) VOC
10) VOC
11) formaldehyde
12) biological material such as fungi and bacteria
17) particulates

Part 3: HVAC Operation

Some of the numbered questions are followed in the same paragraph by other questions requiring a Yes/No answer. A "Yes" answer to the numbered questions *only* indicates that a problem is likely if one or more "Yes" answers are obtained to the other questions in the same paragraph. The more "Yes" answers, the more chance of a problem.

The types of problems indicated by the answers are indicated below:

14) and 15) Less than 10% fresh air is likely to result in non-compliance with ASHRAE standards.
16) VAV boxes respond to temperature, and may not be effective in dealing with strong local pollution sources.
17) If the temperature is higher than 55° C, legionella bacteria cannot survive.
18) — Carbon monoxide may be a problem if the intakes are either just above a busy street, or close to a loading dock or parking garage that have been identified as potential problem sources (check answers to questions (1) and (2));
— particulates may be a problem if there are obstructions in the intake *and* particulate filters either are not used in the HVAC system, or are poorly maintained (check question (20));
— contaminated air from the exhausts can re-enter the building if intakes and exhausts are too close. This will increase concentrations of all pollutants.
20) particulates, see question (18).
21) — biological contamination can be caused by spray humidifiers if the pans are not kept clean;
— particulate problems can be caused by spray humidifiers but *only* if the local water is hard *and* the cleaning procedure allows hard water solids to enter the ventilation ducts.
22) VOCs used to protect the boiler or steam pipes may enter the ventilation system and be distributed around the building.
23) Biological contamination can result if the air-conditioning system is not cleaned regularly. Most outbreaks of legionellosis are caused in this way, and fungal contamination is also possible.
24) Particulates originating in the ducts or plenums; these can be accumulated dirt, or insulation fibers (if the insulation is on the inside of the duct or plenum). If the insulation looks like it is a problem, check to see whether it is asbestos. Building Performance can supply information on PWC's asbestos program.

Part 4: Maintenance and Design

Some of the numbered questions are followed in the same paragraph by other questions requiring a Yes/No answer. A "Yes" answer to the numbered questions *only* indicates that a problem is likely if one or more "Yes" answers are obtained to the other questions in the same paragraph. The more "Yes" answers, the more chance of a problem.

The types of problems indicated by "Yes" answers are indicated below:

26) inadequate ventilation (fresh air or air circulation)
27) temperature/carbon dioxide
28) carbon dioxide
29) VOC
30) VOC
31) formaldehyde. If the answer here is "do not know," check the building plans, which should contain this information. If this is unsuccessful, extract a small piece of the insulation from the wall cavity, and send it to Building Performance for testing.

Part 5 — COMPLAINT AREA OBSERVATION SHEET

To do the assessment, place this sheet to the right of the completed COMPLAINT AREA OBSERVATION SHEET, and overlap it, so that the numbered paragraph headings line up (a ruler is useful). The assessment for each answer can then be read off directly.

1) *General Observations*
Yes = biological
Yes = possible biological (mold). Check answer to next question
Yes = increases the probability of biological problem
Yes = almost any pollutant. To try to determine which one, check descriptions against the table of odours on the next page and enter the most likely:

Yes = carbon dioxide (ventilation)
Yes = particulates

2) *Enclosed Office* = Yes
Yes (*no* thermostat) = temperature / carbon dioxide (ventilation)

3) *Open Office* = Yes
Yes = carbon dioxide (local air circulation)
Yes increases probability of carbon dioxide (local air circulation)
Yes increases probability of carbon dioxide (local air circulation average area less than 100 sq. ft. increases the probability

4) *Air Supply Diffusers*
Yes = carbon dioxide (ventilation)
mold = biological; *chalky dust* = particulates from struc-

tural alterations *or* spray humidifier: *dirt marks* = particulates in the ventilation system
Yes = carbon dioxide

5) *Air Exhaust Louvers*
Yes = carbon dioxide (ventilation)
Yes = particulates in the room or nearby
Yes = carbon dioxide

6) *Pollutant Sources* within 30 feet (10 meters)
Yes – check question 7 for likely source strength (VOC)
Yes – check question 8 for likely source strength (VOC)
Yes – check question 9 for likely source strength (VOC)
Yes – check question 10 for likely source strength (VOC)
Yes – check question 11 for likely source strength (formaldehyde)
Yes – check question 12 for likely source strength (particulates)
Yes – check question 13 for likely source strength (particulates)

APPENDIX B

INDOOR AIR QUALITY SURVEY

This questionnaire is designed to help assess the quality of the indoor environment at _____.

Your answers will remain confidential and they will be used for analyses only.

The questionnaire is collecting data on your working environment, health and lifestyle. Questions are answered by checking the appropriate

box ☑ , circling the appropriate answer (glare), or by filling in a blank _____. There is also space for additional comments.

We are grateful for your help in completing this questionnaire. Please check that you have answered all the questions before sealing the questionnaire in the confidential return envelope.

Hand the sealed envelope to _____
who will be in the office while you are completing the questionnaire.

Date: _____ Time: _____

DESCRIPTION OF JOB AND OFFICE

(1) What is your employment status?

Full time ..... ☐
Part time ..... ☐
Temporary ..... ☐
Other (Specify) _____

(2) I have worked in this area since (year) _____, (month) _____, (day) _____.

(3) How many hours per week do you work in this area? _____ hours.

(4) I am in:

a closed office ☐
my own cubicle ☐
an open area shared with others ☐
Other _____
(Specify)

(5) What is the location of your desk? (Identify on floor map if attached.)

(6) Are you sitting within 3.7 meters (12 feet) of a window?

Yes ☐ No ☐

(7) Can the window be opened?

Yes ☐ No ☐

(8) Within 10 metres (approximately 33 feet) of your work location is there:

(a) typewriter. . . . . Yes ☐ No ☐
(b) a photocopying machine? . . . . . Yes ☐ No ☐
(c) a keyboard with a video display screen
(e.g. VDT, CRT, data or word processor)? . . . Yes ☐ No ☐
(d) a printer . . . . . Yes ☐ No ☐
(e) a teletype or fax machine? . . . . . Yes ☐ No ☐
(f) posting-machine? . . . . . Yes ☐ No ☐
(f) other (specify)? _____

(9) For each equipment that you work with, list the number of hours that you use the machine on a typical day.

Equipment	Hours per day
_____	_____
_____	_____
_____	_____

DURING THE PREVIOUS WEEK WHILE WORKING IN YOUR AREA:			
Check "Yes" if symptoms interferred with work.	Circle the symptoms which have given you trouble.	How long did the symptoms last?	Circle when the symptoms are worst?
(10) Nasal symptoms Yes ☐ → No ☐ ↓	nosebleeds, congestion, sinus problems, sneezing, runny nose, dry nose, other: _____ (specify)	_____ (hours)	Mon: am pm Tues: am pm Wed: am pm Thurs: am pm Fri: am pm
(11) Throat Symptoms Yes ☐ → No ☐ ↓	sore throat, dry cough, other: _____ (specify)	_____ (hours)	Mon: am pm Tues: am pm Wed: am pm Thurs: am pm Fri: am pm
(12) Eye symptoms Yes ☐ → No ☐ ↓	redness, watering, burning, puffiness, dryness, irritation, blurred vision, other: _____ (specify)	_____ (hours)	Mon: am pm Tues: am pm Wed: am pm Thurs: am pm Fri: am pm

DURING THE PREVIOUS WEEK WHILE WORKING IN YOUR AREA:			
Check "Yes" if symptoms interferred with work.	Circle the symptoms which have given you trouble.	How long did the symptoms last?	Circle when the symptoms are worst?
	CONTACT LENS WEARERS ONLY		
(13) Problems related to wearing contact lenses Yes ☐ → No ☐ ↓	problems with: cleaning, deposits, discomfort, pain, other: _____ (specify)	_____ (hours)	Mon: am pm Tues: am pm Wed: am pm Thurs: am pm Fri: am pm
(14) Skin Problems Yes ☐ → No ☐ ↓	Dryness, flaking, rash, irritation, other: _____ (specify)	_____ (hours)	Mon: am pm Tues: am pm Wed: am pm Thurs: am pm Fri: am pm
(15) Aches and Pains Yes ☐ → No ☐ ↓	headache, backache, muscle/joint pain, other:_____ (specify)	_____ (hours)	Mon: am pm Tues: am pm Wed: am pm Thurs: am pm Fri: am pm
(16) General Complaints Yes ☐ → No ☐ ↓	drowsiness, dizziness, faintness, difficulty in concentration, other: _____ (specify)	_____ (hours)	Mon: am pm Tues: am pm Wed: am pm Thurs: am pm Fri: am pm

DURING THE PREVIOUS WEEK WHILE WORKING IN YOUR AREA:

Check "Yes" if symptoms interferred with work.	Circle the symptoms which have given you trouble.	How long did the symptoms last?	Circle when the symptoms are worst?
(17) Other symptoms Yes ☐ → No ☐ ↓	breathing, digestive, menstrual, other: _____ (specify)	_____ (hours)	Mon: am pm Tues: am pm Wed: am pm Thurs: am pm Fri: am pm

(18) Were you ever absent because of any health problem(s) that you feel may have been caused or aggravated by working at your present location?

Yes ☐ → If yes, state the health problem: _____

No ☐ ↓

(19) Did you seek medical treatment because of any health problem(s) caused or aggravated by working at your present location?

Yes ☐ No ☐

WORKING ENVIRONMENT: Please record your general assessment of the working environment at your present location.

Check "Yes" if disturbing	Circle the aspects which are disturbing	Circle when the problems are most disturbing?
(20) Noise Yes ☐ → No ☐ ↓	Noise from: • nearby conversation • lighting • ventilation system • office equipment • other _____ (specify)	Mon: am pm Tues: am pm Wed: am pm Thurs: am pm Fri: am pm
(21) Ventilation Yes ☐ → No ☐ ↓	• temperature • humidity • air movement • other _____ (specify)	Mon: am pm Tues: am pm Wed: am pm Thurs: am pm Fri: am pm
(22) Lighting Yes ☐ → No ☐ ↓	• too bright • not bright enough • glare, flicker • other _____ (specify)	Mon: am pm Tues: am pm Wed: am pm Thurs: am pm Fri: am pm
(23) Others Yes ☐ → No ☐ ↓	Specify: _____ _____ _____	Mon: am pm Tues: am pm Wed: am pm Thurs: am pm Fri: am pm

(24) If there is a smell in your area, how would you describe the smell?

(a) The smell resembles:

- Glue ..... ☐
- vinegar ..... ☐
- alcohol ..... ☐
- ammonia ..... ☐
- propane ..... ☐
- gasoline ..... ☐
- perfume ..... ☐
- other _____ (specify)

(b) It smells:

- smoky ..... ☐
- dusty ..... ☐
- musty ..... ☐
- stale ..... ☐
- other _____ (specify)

(25) In your opinion, where is the smell coming from?

_____

_____

(26) Do you use any of the following in your work location?

Check appropriate box:

- (a) a desk lamp ..... ☐
- (b) a fan ..... ☐
- (c) a heater ..... ☐
- (d) humidifier ..... ☐
- (e) an ion generator ..... ☐
- (f) an air cleaner ..... ☐
- (g) personal care products (e.g. hand cream, hairspray) .... ☐

  (Please specify what products) _____ ☐
- (h) No items

(27) Have you any control over your work location? Check appropriate box:

(a) ventilation ..... ☐
(b) temperature ..... ☐
(c) humidity ..... ☐
(d) lighting ..... ☐

(28) Is smoking allowed in or near your working location?

No ☐ → If No go to question 32.
Yes ☐

(29) How many cigarettes a day do you smoke at your work location?

None ..... ☐
Less than 10 ..... ☐
Between 10 and 30 ..... ☐
More than 30 ..... ☐

(30) Do you smoke any other tobacco product at your work location (e.g. pipe, cigar)?

Yes ☐ → Amount smoked per day:
No ☐ Cigars _____
Ounces of tobacco _____

(31) Do other people smoke in your area?

Yes ☐ No ☐

(32) Is there a designated smoking area?

Yes ☐ No ☐

(33) Do you have allergies?

Yes ☐ No ☐

Yes you are allergic to: _____

(34) Are you taking any prescribed medication for any symptoms you mentioned?

Yes ☐ No ☐

GENERAL INFORMATION

(35) Age (in years) _____

(36) Sex: Male

Female

ARE THERE ANY FURTHER COMMENTS WHICH YOU WOULD LIKE TO MAKE?

_____

_____

_____

THANK YOU FOR FILLING IN THIS QUESTIONNAIRE

APPENDIX C

A) Analysis of Individual Responses

For answers relating to symptoms only those symptoms which occur during working hours will be considered.

Contaminant - 1
VOC

1. Symptoms - Incidence and Severity

Q.10 Score	Q.12 Score	Q.13 Score	Q.14 Score
10.1.3	12.1.1	13.1.1	14.1.1
10.1.4	12.1.2	13.1.2	14.1.2
10.1.5	12.1.3	13.1.3	14.1.3
	12.1.4	13.1.4	14.1.4
	12.1.5		
	12.1.6		
Sum	Sum	Sum	Sum

Total Score _____

2. Exposure

Q.8 Score	Q.9 Score	Q.24 Score	Q.26 Score
8.1	9.1	24.1.1	26.7
8.3	9.3	24.1.2	
8.4	9.4	24.1.3	
8.5	9.5	24.1.4	
Sum	Sum	Sum	Sum

Total Exposure Score _____

Contaminant - 2
Formaldehyde

1. Symptoms

Q.11 Score
11.1.1
11.1.2
11.1.3
Sum =

Total Score _____

2. Exposure

Q.24 Score
24.1.5
24.1.6
24.2.1
Sum =

Total Exposure Score _____

Contaminant - 3
Ozone

1. Symptoms

Q.10 Score	Q.11 Score
10.5	11.1
	11.2
	11.3
	11.4
	11.5
Sum=	Sum=

Total Score _____

2. Exposure

Q.8 Score	Q.9 Score
8.1	9.1
Sum=	Sum=

Total Exposure Score _____

Contaminant - 4
Carbon Monoxide - CO

1. Symptoms

2. Exposure

Q.24 Score	Q.29 Score	Q.30 Score	Q.31 Score
24.1.5	29.2	30	31
24.1.6	29.3		
24.2.1	29.4		
Sum=	Sum=	Sum=	Sum=

Total Exposure Score _____

Other Factors-5
Relative Humidity

1. Symptoms

Q.10 Score	Q.11 Score	Q.16 Score
10.1.1	11.1.7	16.1.1
10.1.2		16.1.2
10.1.3		16.1.3
		16.1.4
Sum =	Sum =	Sum =

Total Score _____

2. Exposure

Q.24 Score	Q.26 Score	Q.27 Score
24.2.3	26.4	27.3
Sum =	Sum =	Sum =

Total Exposure Score _____

Other Factors - 6
Carbon Dioxide - CO_2

1. Symptoms

N/A

2. Exposure

Q.24 Score
24.2.1
24.2.4
Sum =

Total Exposure Score _____

Other Factors - 7
Temperature

1. Symptoms

   N/A

2. Exposure

Q.21	Score	Q.26	Score
21.1		26.2	
		26.3	
Sum =		Sum =	

Total Exposure Score _____

Other Factors - 8
Air Movement

1. Symptoms

Q.21	Score
21.1.3	
Sum =	

Total Score _____

2. Exposure

Q.26	Score
26.2	
Sum =	

Total Exposure Score _____

CONTAMINANT - 10
-BIOLOGICAL SUBSTANCES

1. Symptoms

Q.18	Score	Q.19	Score
18.1		19.1	
Sum=		Sum=	

Total Symptoms Score =

2. Exposure

Q.21	Score	Q.26	Score
21.2		26.4	
Sum=		Sum=	

Total Exposure Score =

CONTAMINANT - 11
PARTICULATES

1. Symptoms

   N/A

2. Exposure

Q.24	Score	Q.29	Score	Q.30	Score	Q.31	Score
24.2.1		29.2		30.1		31.1	
24.2.2		29.3					
24.2.4		29.4					
Sum=		Sum=		Sum=		Sum=	

Total Exposure Score =

Stress Factors - 9
Noise, Lighting, etc.

1. Symptoms

Q.12	Score	Q.16	Score
12.1		16.1.1	
12.2		16.1.2	
12.3		16.1.3	
12.4		16.1.4	
12.5		16.1.5	
12.6			
Sum =		Sum =	

Total Score _____

2. Exposure

Q.7	Score	Q.20	Score	Q.22	Score
7.2		20.1		22.1.1	
		20.2		22.1.2	
		20.3		22.1.3	
Sum =		Sum =		Sum =	

Total Exposure Score _____

CONTAMINANT - 12
SECOND HAND SMOKE

1. Symptoms

Q.10	Score	Q.12	Score	Q.15	Score	Q.16	Score
10.3		12.1		15.1.1		16.1.1	
10.4		12.2					
10.6		12.3				Q.17	
		12.6				17.1.1	
Sum=		Sum=		Sum=		Sum=	

Total Symptoms Score =

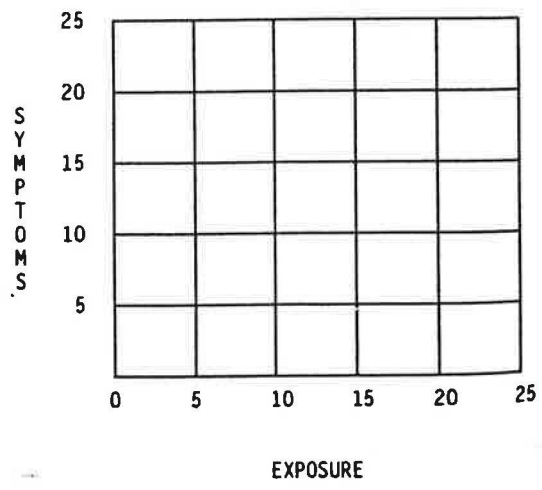
2. Exposure

Q.31	Score
31.1	
Sum=	

Total Exposure Score =

APPENDIX D

CONTINGENCY TABLE



APPENDIX D

TOTAL SCORE TABLE

QUESTIONNAIRE NO	SYMPTOMS												EXPOSURE											
	1 VOC	2 FOR	3 OZO	4 CO	5 RH	6 CO_2	7 T	8 AIR	9 STR.	10 BIO	11 PAR	12 SMO	1 VOC	2 FOR	3 OZO	4 CO	5 RH	6 CO2	7 T	8 AIR	9 STR.	10 BIO	11 PAR	12 SMO
1																								
2																								
3																								
4																								
5																								
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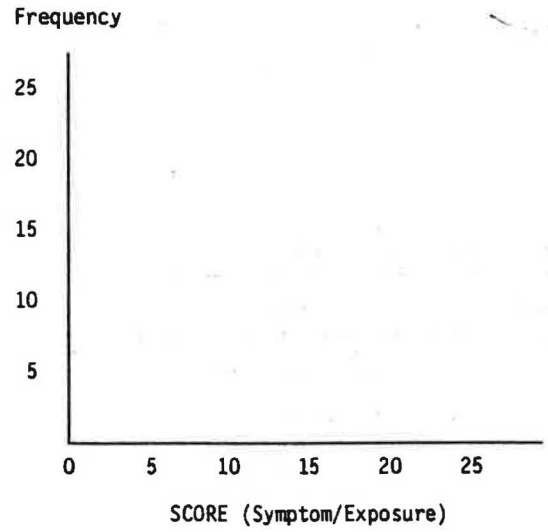
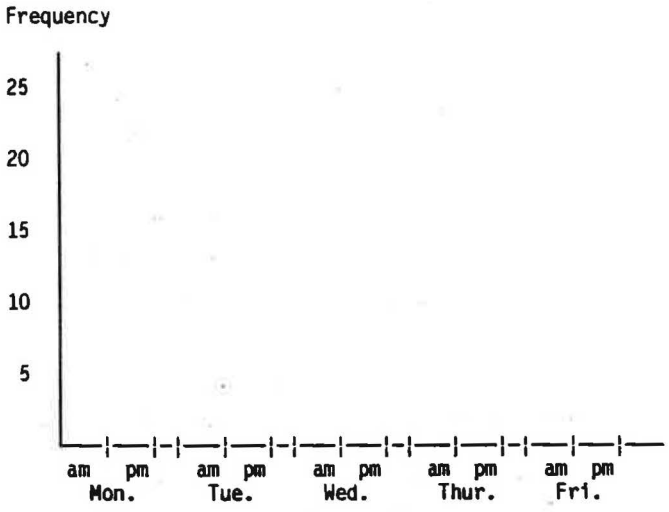
FREQUENCY DISTRIBUTION FOR EACH CONTAMINANT SYMPTOMS/EXPOSURE



FREQUENCY DISTRIBUTION FOR DAYS OF THE WEEK



APPENDIX E

WHERE AND WHEN TO MEASURE
(SOURCE: Public Works Canada. Indoor Air Quality Test Kit: User Manual, 1988.)

TABLE 1

Test Locations for Measuring Pollutants and Other Parameters Related to Indoor Air Quality

Pollutant or Parameter	Test locations	Time to measure
carbon dioxide	pollutant sources (questions 31, 32) complaint areas	late morning, late afternoon, when fresh air rate low
carbon monoxide combustion	pollutant sources (questions 1–5, 22) complaint areas near sources	early morning, late afternoon, when fresh air rate low
formaldehyde	pollutant sources (building) (questions 15, 35) complaint areas near sources	early morning, when fresh air rate low
particulates	pollutant sources (questions 16, 17, 24, 28) complaint areas near sources	
VOC	pollutant sources (building) (questions 14, 26) complaint areas near sources	early morning, Mondays, when fresh air rate low
VOC	pollutant sources (activity) (questions 12, 13, 33, 34) complaint areas near sources	late morning, late afternoon, when fresh air rate low
biological contamination	pollutant sources (building) (question 27) complaint areas near sources	early morning, Mondays, when fresh air rate low, summer
temperature	areas without a thermostat complaint areas	early mornings, late afternoons
humidity	supply air complaint areas	mornings, Mondays, midwinter, midsummer
air movement	near diffusers, exhaust complaint areas	doesn't matter

TABLE 2

Suitable Control Locations for Measuring Pollutants

Pollutant	Suitable control location
carbon dioxide	air intakes (if not contaminated) outdoors, street level or roof indoors, unoccupied area
carbon monoxide	air intakes (if not contaminated) outdoors, roof or upper floor indoors, above second floor
formaldehyde	air intakes (if not contaminated) outdoors, sheltered area (no wind or rain) indoors, lobby or reception area
particulates	air intakes (if not contaminated) outdoors, roof or upper floor on the building side of particulate filters indoors, unoccupied area
VOC	air intakes (if not contaminated) outdoors, street level or roof indoors, lobby or reception area
biological contamination	air intakes (if not contaminated) outdoors, roof indoors, area with no mould, no water, no plants

APPENDIX F

Data Assessment Table

POLLUTANT (measurement units)	MEASURED CONCENTRATIONS normal outdoor	normal indoor	possible problem	do not exceed
CARBON DIOXIDE (ppm)	330–400	330–800	800–1000	1000
CARBON MONOXIDE (ppm)	0–4	0–4	4–11	11
FORMALDE-HYDE (ppm)	0–0.02	0–0.1	0.05–0.01	0.1
NITROGEN DIOXIDE (ppm)	0–0.04	0–0.04	0.03–0.05	0.05
OZONE (ppm)	0–0.03	0–0.10	0.05–0.1	0.1

The measured values of temperature and relative humidity should also be compared to the ranges allowed by ASHRAE. These are:
winter temperature: 19.5–24.6°C;
summer temperature: 22.6–27.2°C;
winter humidity: 25–85%;
summer humidity: 25–70%

In regions with cold, dry winters and hot, damp summers, the humidity limits are effectively: not less than 25% RH in winter, and not more than 70% in summer.

If temperatures or humidities at the extremes of these ranges are recorded, this indicates a "possible problem." Measured values outside the extremes are effectively in the "do not exceed" column of the table.

For air movement in the occupied zone, average winter air movement should not exceed 0.15 m/s (30 fpm). Average summer air movement should not exceed 0.25 m/s (50 fpm).

APPENDIX G

Instrumentation for Simple Field Measurements

Pollutant/Cause	Equipment	Units of Measurement
Carbon Dioxide	Fuji ZFP5 Horiba APBA-210	PPM PPM
Carbon Monoxide	ISD C0260 Dynamation 104 Gastec Colorimetric Tube	PPM PPM
Formaldehyde	ATL Chemical Kit Pro-Tek Passive Dosimeter	PPM
VOC	Gastec Pump and Tubes	PPM
Relative Humidity (RH)	Vaisala HMI 31 HMP-31UT	%
Temperature (T)	Vaisala HMI 31 HMP-31UT	C or F
Air Movement	Gastec Smoke Tube Kit	none
Respirable Suspended Particulates (RSP)	MDA-PDC-1 Digital Dust Counter	mg/m

TABLE 1

Requirements	Outdoor Air Requirements cfm/person
Assembly Occupancies Intended for the Production and Viewing of the Performing Arts	
Motion picture theaters	15
Opera houses	15
Television studios admitting a viewing audience	15
Theaters, including experimental theaters	15
Other Assembly Occupancies	
Art galleries	15
Auditoria	15
Churches and similar places of worship	15
Clubs, nonresidential	15
Community halls	15
Court rooms	15
Day-care centers	15
Exhibition halls, other than in Group E	15
Gymnasia	15
Lecture halls	15
Libraries	15
Museums	15
Schools and colleges, nonresidential (excluding laboratories)*	15
Institutional Occupancies	
Jails	20
Penitentiaries	20
Police stations with detention quarters	15
Prisons	20
Psychiatric hospitals with and without detention quarters	15
Reformatories with detention quarters	15
Children custodial homes	15
Convalescent homes	15
Hospitals (excluding patient rooms and operating rooms)**	15
Infirmaries	15
Nursing homes	15
Orphanages	15
Reformatories without detention quarters	15
Sanitoria without detention quarters	15
Business and Personal Services Occupancies	
Banks	15
Offices	15
Police stations without detention quarters	15
Mercantile Occupancies	
Department stores	15
Exhibition halls	15

* Laboratories should have at least 25 cfm/person

NOTE: 15 cfm/person = 7.5 L/sec/person
20 cfm/person = 10 L/sec/person

** Patient Rooms and Operating Rooms should have at least 25 to 30 cfm/person

TABLE 2

Summary of Indoor Pollutants, Emissions Sources, and Concentrations (Spengler and Sexton 1983)

Pollutant	Major Emission Sources	Typical Indoor Concentrations in the Presence of Indoor Emission Sources	Indoor/ Outdoor Concentration Ratio (5)
	Origin: predominantly outdoors		
Sulfur oxides (gases, particles)	Fuel combustion, smelters	0–15 ug/m^3	L
Ozone	Photochemical reactions	0–10 ppb	L
Pollens	Trees, grass, weeds, plants	L.V. (1)	L
Lead, manganese	Automobiles	L.V.	L
Calcium, chlorine, silicon, cadmium	Suspension of soils, industrial emissions	N.A. (2)	L
Organic substances	Petrochemical solvents, natural sources, vaporization of unburned fuels	N.A.	L
	Origin: indoors or outdoors		
Nitric oxide, nitrogen dioxide	Fuel burning	10–120 ug/m^3 (3) 200–700 ug/m^3 (4)	VG
Carbon monoxide	Fuel burning	5–50 ppm	VG
Carbon dioxide	Metabolic activity, combustion	2000–3000 ppm	VG
Particles	Resuspension, condensation of vapours, combustion products	10–1000 ug/m^3	E
Water vapor	Biological activity, combustion evaporation	N.A.	G
Organic substances	Volatilization, combustion, paint, metabolic action, pesticides	N.A.	VG
Spores	Fungi, molds	N.A.	G
	Origin: predominantly indoors		
Formaldehyde	Particleboard, insulation, furnishings, tobacco smoke	0.01–0.5 ppm	G
Asbestos, mineral and synthetic fibers	Fire retardant materials, insulation	0–1 fiber/mL	E

TABLE 2

Summary of Indoor Pollutants, Emissions Sources, and Concentrations (Spengler and Sexton 1983)

Pollutant	Major Emission Sources	Typical Indoor Concentrations in the Presence of Indoor Emission Sources	Indoor/ Outdoor Concentration Ratio (5)
Organic substances	Adhesives, solvents, cooking, cosmetics	L.V.	G
Ammonia	Metabolic activity, cleaning products	N.A.	G
Polycyclic hydrocarbons, arsenic, nicotine, acrolein, and so forth	Tobacco smoke	L.V.	VG
Mercury	Fungicides, paints, spills in dental-care facilities or labs, thermometer breakage	L.V.	G
Aerosols	Consumer products	N.A.	VG
Microorganisms	People, animals, plants	L.V.	G
Allergens	House dust, animal dander, insect parts	L.V.	VG

(1) — LV, limited and variable (limited measurements, high variation)
(2) — NA, not applicable
(3) — annual average
(4) — one-hour average in homes with gas stoves, during cooking
(5) — L, less than 1; G, greater than 1; VG, very much greater than 1; E, equal to 1

SOURCE: Spengler and Sexton 1983)

(SOURCE: Nero 1988)

TABLE 3

Air Pollutant Criteria in ASHRAE Standards 62–1981 and 62–1981R

a) Criteria for Make-up Air (U.S. EPA):		
Sulfur Dioxide	0.03 ppm (year);	0.14 ppm (24 hours)
Total particulate	75 ug/m^3 (year);	260 ug/m^3 (24 hours)
Carbon monoxide	9 ppm (8 hours);	35 ppm (1 hour)
Ozone	—	0.12 ppm (1 hour)
Nitrogen dioxide	0.055 ppm (year)	
Lead	1.5 ug/m^3 (3 months)	
b) Criteria for Indoor Air:		
Standard 62–81:		
Formaldehyde	0.1 ppm (0.12 mg/m^3)	
Standard 62–81R:		
Carbon Dioxide	1000 ppm (1.8 g/m^3)	
Both:		
Chlordane	0.0003 ppm (5 ug/m^3) (continuous)	
Ozone	0.05 ppm (100 ug/m^3)	

TABLE 4

Relationships Among Extent of Complaints Regarding Indoor Air Quality, CO_2 Levels and Ventilation Rates

Comments	CO_2 (ppm)	Ventilation Rate/Person CFM	L/s
Occasional complaints, particularly if the air temperature rises	600	35	16.5
Complaints are more prevalent	800	21	10
Insufficient make-up air, complaints more general	1000	15	7

TABLE 5

The Conversion of Indoor Carbon Dioxide Levels to Effective Ventilation Rates

Carbon dioxide readings can be used to indicate effective ventilation rates in occupied buildings, according to the following approximate formula derived from ASHRAE Standard 62–1981:

Effective Ventilation Rate (in L/sec/person)
= 5000/([CO_2] ppm − 340)

(Note: 340 ppm is a typical ambient CO_2 level for downtown areas.)

Thus a CO_2 reading of 1000 ppm will require an effective ventilation rate = 5000/(1000 − 340) = 7.57 L/sec/person or 15.10 cfm/person.

TABLE 6

Occupational Limits for Selected Chemicals

Chemical	ACGIH 1/ mg/m³ (ppm)	Occ. Health & Safety Act — Ontario 2/ mg/m³ (ppm)
Acetaldehyde	180 (100) 270 (150)	180 (100) 270 (150)
Acrolein	0.25 (0.1) 0.8 (0.3)	0.23 (0.1) 0.7 (0.3)
Formaldehyde	1.5 (1) 3 (2)	1.5 (1) 3 (2)
Carbon dioxide	9000 (5000) 54,000 (30,000)	9000 (5000) 54,000 (30,000)
Carbon monoxide	55 (50) 440 (400)	40 (35) 460 (400)
Nitrogen dioxide	6 (3) 10 (5)	5.6 (3) 9.4 (5)
Sulfur dioxide	5 (2) 10 (5)	5.1 (2) 104 (5)

1/ American Conference of Governmental and Industrial Hygienists. The upper number represents time-weighted average threshold limit value; the lower, the short-term exposure threshold limit value.

2/ Occupational Health and Safety Act, R.S.O. 1980, c. 321. Ontario Regulation 654/86 as amended by Ontario Regulations 707/86.

The upper number represents time-weighted average exposure; the lower, the short-term exposure.

TABLE 7

Indoor Air Quality Guidelines (Prepared by the World Health Organization (WHO, 1984) Consensus of Concern about Indoor Air Pollutants at 1984 Levels of Knowledge

Pollutant [a]	Concentrations Reported [b]	Concentrations of limited or no concern [b]	Concentrations of concern [b]	Remarks
Tobacco smoke (passive smoking)				
• Respirable particulates	0.05–0.7	<0.1	<0.15	Japanese standard 0.15 mg/m³
• CO	1–1.5	<2	>5	Indicator for eye irritation (only from passive smoking)
• Nitros-dimethylamine	(1–50) × 10^{-6}	—	—	Mutagens under investigation for carcinogenicity
NO_2	0.05–1	<0.19	>0.32	
CO	1–100	2% COHb <11	3% COHb >30	99.9% Continuous exposure
Formaldehyde	0.05–2	<0.06	>0.12	Long and short term
SO_2	0.02–1	<0.5	>1.35	SO_2 alone, short term
CO_2	600–9000	<1800	>12,000	Japanese standard, 1800 mg/m³
O_3	0.04–0.4	0.05	0.08	
Asbestos	<10 fibers/m³	0	10^5 fibers/m³	For long-term exposure
Mineral fibers	<10 fibers/m³	—	—	Skin irritation
Organics			(ug/m³)	
• Methylene chlorine	0.005–1	—	350 260	TLV [d] NIOSH [e] recommendations
• Trichloroethene	0.0001–0.02	—	270 135	TLV NIOSH recommendations
• Tetrachloroethene	0.002–0.05	—	335	TLV
• 1, 4-Dichlorobenzene	0.005–0.1	—	450	TLV
• Benzene	0.01–0.04		carcinogen carcinogen	
• Toluene	0.015–0.07	—	375	TLV
• m, p-Xylene	0.01–0.05	—	435	TLV
• n-Nonane	0.001–0.03	—	1050	ILO [f](1980)
• n-Decane	0.002–0.04	—	—	
• Limonene	0.01–0.1	—	560	TLV turpentine

TABLE 7 (Continued)

Indoor Air Quality Guidelines (Prepared by the World Health Organization (WHO, 1984) Consensus of Concern about Indoor Air Pollutants at 1984 Levels of Knowledge

Pollutant [a]	Concentrations Reported [b]	Concentrations of limited or no concern [b]	Concentrations of concern [b]	Remarks

[a] All gases were considered on their own without other contaminants
[b] Typical ranges of concentration given in mg/m^3 unless otherwise indicated, and for short-term exposures
[c] According to Environmental Health Criteria No. 4, Geneva, World Health Organization, 1977
[d] TLV (threshold limit values) established by the American Conference of Governmental Industrial Hygienists (1983/1984). These values are for industrial exposures and should be considered as extreme upper limits for non-occupation populations for very short-term exposures.
[e] NIOSH — National Institute for Occupational Safety and Health U.S.A.
[f] ILO — International Labour Organization
— No meaningful numbers can be given because of insufficient knowledge

TABLE 8

Summary of Exposure Guidelines for Indoor Air Quality. Developed by a Working Group of the Federal/Provincial Advisory Committee on Environmental and Occupational Health (HWC 1987)

Contaminant	Some Possible Health Effects	Acceptable Exposure Ranges Aster ug/m^3 (ppm)	Alter
Aldehydes (total)	Eye, nose, throat irritation	$c_i/C_i<1$([1]) – 5m	—
Carbon Dioxide	Acidosis	–	<6300 (<3500)
Carbon Monoxide	Adverse effects on cardiovascular system	(<11) – 8 h ([2]) (<25) – 1 h ([2])	—
Formaldehyde		([3])	([3])
Nitrogen Dioxide	Respiratory disease; Respiratory irritation; Impaired lung function	<480 (<0.25) – 1 h	<100 (<0.05)
Ozone		<240 (<0.12) – 1 h	—
Particulate Matter ([4])		<100 – 1 h	<40
Sulphur Dioxide		<1000 (<0.38) – 5 m	<50 (<0.019)

[1] C_i = 120 ug/m^3 - formaldehyde; 50 ug/m^3 - acrolein; 9000 ug/m^3 - acetaldehyde, and c_i are respective concentrations measured over a 5-minute period.

[2] Units given only in parts per million so that guidelines are independent of ambient pressure.

[3] See Aldehydes (total). Since formaldehyde is considered a potential human carcinogen, every effort should be made to reduce exposure levels to the lowest possible level. The exposure guidelines are expressed in terms of what can be attained now, given as the action level 120 ug/m^3 (0.1 ppm) and what should be striven for air longer-term objectives, given as the target level 60 ug/m^3 or 0.05 ppm.

[4] <2.5 um mass median aerodynamic diameter.

TABLE 9

Standards and Guidelines for Ambient Air for Selected Chemicals.

Chemical	Federal 1/ ug/m^3 (ppb)	Ontario 2/ ug/m^3 (ppb)	US-EPA 3/ ug/m^3 (ppb)
Carbon monoxide	0 – 6000 – 8h 6000 – 15,000 – 8h	6000 15,000 – 8h	10,000 (9000) – 8h
Formaldehyde	—	65(50) 65 – 1h	—
Nitrogen dioxide	—	500 200 – 24h	100 (53) – annual arithmetic mean
Ozone	0 – 30 – 24th 30 – 50 – 24h	200 165 – 1h	235 (120) – 24h
Particulate matter	0 – 60 60 – 70	100 (d <44 um) 60 – 1 yr	150 – 24h (d <10 um)
Sulfur dioxide	0 – 30 30 – 60	830 55 – 1 yr	1300 (500) – 3

1/ The upper and lower ranges represent the desirable and acceptable values set by regulation under the Clean Air Act 1970-71-72, C-47. The numbers, unless stated otherwise, are annual arithmetic means. The geometric annual mean is used for particulate matter.

2/ The upper value is the point of impingement value, averaged over 30 m (Regulation 308, General-Air Pollution, RRO, 1980). The lower is the ambient air criterion, averaged over the given time periods.

3/ The first values are national primary and/or secondary air quality standards. Unless otherwise noted, they are the maximum concentration during the time periods stated which is not to be exceeded more than once per year. These are set under Section 109 of the Clean Air Act.

TABLE 10

Contaminants for Which Numerical Guidelines were not Set by Working Group on Indoor Air Quality [1/]

Contaminant	Some Possible Health Effects	Recommendation
Biological Agents	Infectious disease; allergies	Prevent excess humidity and condensation. Keep surfaces clear of dust. Keep stagnant water sources such as humidifier tanks clean, and occasionally disinfect them. Maintain a high standard of personal hygiene.
Consumer Products (chlorinated hydrocarbons, pest control products, product aerosols)	Damage to central nervous system, allergic reactions	Ensure adequate ventilation and observe any other precautionary measures described on the product label and in any accompanying information. Use pesticides only when absolutely necessary.
Fibrous Materials	Lung cancer; skin irritation	Minimize inhalation of, and skin contact with, mineral fibers during renovations and installation operations. Examine materials and products containing fibers periodically for signs of deterioration. Seek advice before removing or damaging any materials thought to contain asbestos.
Lead	Learning impairment; neurological disorders	Minimize exposure, especially of children, to lead of airborne origin by frequently cleaning contaminated surfaces.
Polycyclic Aromatic Hydrocarbons (PAHs)	Lung cancer	Ensure that any combustion systems are properly installed and maintained, and operated under conditions of satisfactory ventilation.
Tobacco Smoke	Lung cancer; sensory and respiratory irritation	Avoid any exposure to tobacco smoke.

1/ Armstrong et al. 1988.

TABLE 11

Control Measures for Indoor Air Pollutants

Ventilation: Dilution of indoor air with fresh outdoor air or recirculated filtered air, using mechanical or natural methods to promote localized, zonal, or general ventilation	Combustion by-products; tobacco smoke; biological agents (particles); organic substances, etc.	Local exhaust of emissions; air-to-air heat exchangers; building ventilation codes
Source removal or substitution: Removal of less hazardous materials or products	Organic substances; asbestiform minerals; tobacco smoke	Restrictions on smoking in public places; removal of asbestos and use of less volatile products
Some modification: Reduction of emission rates through changes in design or processes; containment of emissions by barriers or sealants	Organic substances; asbestiform minerals; combustion by-products	Containment of asbestos and volatile substances
Air cleaning: Purification of indoor air by gas adsorbers, air filters, and electrostatic precipitators	Particulate matter; combustion by-products; biological agents (particles)	Air cleaners to control tobacco smoke; ultraviolet irradiation to decontaminate ventilation air; formaldehyde sorbant filters
Behavioral adjustment: Reduction in human exposure through modification of behavior patterns; facilitated by consumer education, product labeling, building design, warning devices, and legal liability	Organic substances; combustion by-products; tobacco smoke	Smoke-free zones; architectural design of interior space; certification of materials for construction

(SOURCE: Spengler and Sexton 1983)