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REPORT OF THE

INTERMINISTERIAL COMMITTEE ON

INDOOR AIR QUALITY

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PREFACE

The environmental awareness of the 1960s and 1970s has spilled over into other areas. One new area of concern is the indoor environment of our homes, offices and schools. This has received increasing attention by the occupants, ventilation engineers, and other specialists. Not only do people spend on average 70-90% of their time indoors, but most new jobs in Ontario are created in the service sector and these employees are usually located in modern offices. It is the indoor environment of the modern office that is often a concern of the occupants.

The energy crisis of the early 1970s prompted building owners to construct energy efficient buildings. They achieved this by constructing "air tight" buildings in which air infiltration and exfiltration were reduced. However, as buildings became more energy efficient, occupants' complaints of the "stuffiness, drowsiness, lack of oxygen, tiredness, eye irritation, nausea and stale air" increased. Several terminologies are used to describe these complaints such as Sick Building Syndrome (SBS), Tight Building Syndrome (TBS) and Closed Building Syndrome (CBS).

The Ontario Ministries of Labour (MOL), Education, Government Services (MGS), and Health and local health units have investigated more than 2,000 indoor air complaints since 1976. Most complaints were reported in air-tight, multi-storey buildings equipped with central HVAC systems (Heating, Ventilation and Air Conditioning systems) and some complaints from schools with or without HVAC. In many cases, the causes of the symptoms could not be found.

Indoor air quality (IAQ) complaints will likely persist in the future and the Ontario Government needs a guideline for defining indoor air parameters and a uniform protocol for investigating "sick building" complaints. This concern about IAQ is shared by many Ministries. On March 30, 1987 at the second meeting of the Deputy Ministers' Committee on Occupational and Environmental Health, a decision was made to set up an Inter-Ministerial Committee to review and evaluate potential hazards to health from buildings and to develop a protocol for investigations of "sick building" complaints. The committee was established and named the Inter-Ministerial Committee on Indoor Air Quality (hence forth, referred to as the Committee).

The Committee met for the first time on July 14, 1987. During its initial deliberations, the Committee sought an approval from the Deputy Ministers' Committee to exclude residential buildings from its deliberations because:

a) a recently released Federal-Provincial report (April 1987) defines acceptable indoor air quality in residential buildings;
b) Ministry of Housing alone has jurisdiction in regulating construction and provision of ventilation methods in residential buildings; and

c) legislative authority with regard to IAQ in residential buildings is not clearly defined.

The Committee also sought an approval to exclude deliberations on second-hand cigarette smoke exposure due to an expected Government-wide policy on this issue.

At their February 2, 1988 meeting, the Deputy Ministers agreed that the Committee's scope would be limited to commercial and institutional buildings, and would exclude residential and industrial buildings. However, the Deputy Ministers asked the Committee to reconsider their decision regarding second-hand smoke exposure. The general opinion of the Deputy Ministers' Committee was that it was neither appropriate nor realistic to exclude the consideration of cigarette smoke since in many cases, it is the most easily identifiable and most easily remedied cause of indoor air quality problems. The Committee reconsidered their position on second-hand smoke at their March 1988 meeting and agreed to address second-hand smoke in their terms of reference. Thus, the final terms of reference agreed upon were as follows:

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

During the period July 1987 - August 1988 the Committee met 11 times to discuss and review the scientific literature and other reports on IAQ in view of the terms-of-reference, and to develop a uniform protocol for the investigation of IAQ complaints. In addition, several Canadian and American governmental personnel working on IAQ problems were also contacted to obtain their views on IAQ standards.

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 with input from MOL hygienists, medical consultants and a statistician. Our protocol is reactive rather than proactive. The Committee did not develop a recommendation for radon because another inter-ministerial committee dealt with this issue. Asbestos, lighting and noise are discussed briefly because the regulations dealing with these agents are either in existence, e.g., asbestos, or in the development stage, e.g., noise and lighting.

The Committee has prepared this report to guide Government inspectors, occupational health professionals, building design professionals, and property managers in recognizing IAQ problems in non-residential and non-industrial buildings and in recommending remedial measures. It is also hoped that this report will lead to a formal policy on IAQ by the Government of Ontario.

The Committee is fully cognizant that, in spite of all the work being done, the understanding of indoor air quality and its health hazards is still incomplete. This is due to the many contaminants involved, the low concentrations of contaminants, and the non-specificity of the reported symptoms. As knowledge grows, the information contained in this report will need updating.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The Committee recommends adoption of uniform definitions of indoor air quality (IAQ) terminologies and a uniform protocol of IAQ investigations. Details are given in the report. 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, ventilation 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 Committee also presents guidelines in this report for IAQ which provide reference points for assessing the extent of remedial measures 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 report are stringent enough to protect the health of school children.

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 Building Code to reflect the findings of this report.

INTRODUCTION

In the last number of years, indoor air quality problems became common when energy conservation measures were introduced for buildings. These measures caused buildings to be more tightly sealed and to have less fresh air circulated.

The complaints and symptoms of illness are the same in most of these buildings. The symptoms are usually not specific so that likely causes of the problems are not easily identified.

1.1 IAQ Issues

The Committee identified seven issues to address on indoor air quality (IAQ). The first issue was defining the terms related to IAQ. Since several terminologies exist to describe "none-specific complaints" related to IAQ, e.g. Sick Building Syndrome, Tight Building Syndrome, it was necessary to first define IAQ and then to choose and define appropriate terms to characterize the common complaints associated with IAQ problems (i.e. eye and upper respiratory irritation, headache, dizziness, nausea, fatigue and perceived stuffiness in the air). Likewise, it was necessary to define "health" before developing the protocol for investigating IAQ complaints.

The second issue was to design a protocol for IAQ investigations which provides consistency in the investigative approach throughout the province. Part of the protocol is a comprehensive questionnaire and its analysis. The purpose of the questionnaire is to allow the investigator to establish 1) whether IAQ problems exist, 2) to what extent, and 3) to help determine the possible sources of contamination. We believe that our protocol will help the investigator in identifying easy, low cost, energy effective solutions if the prescribed three stages are carefully followed.

The third issue was to group the sources of contaminants causing IAQ problems into broad categories. The enormous number of contaminants that have so far been isolated from indoor air were reviewed and a decision was made that they can be grouped under two broad headings:

(1) those which originate from "internal" sources; and
(2) those which 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 source were defined as ambient air infiltration. Common for both sources are temperature, humidity, carbon dioxide, carbon monoxide, formaldehyde, micro-organisms, organic solvents, and odour. Noise, radiation, asbestos, as well as ergonomic and working conditions are excluded from these groups.

The fourth issue was to develop a list of offices and buildings which may encounter IAQ problems due to sealed windows and the presence of HVAC systems. In developing this list (Table 4.5) only those buildings which have extended occupancy, such as places where people are present all day, are considered as opposed to intermittent occupancy such as underground concourses, etc. This was done because places with intermittent occupancy cannot be properly evaluated using our protocol.

The fifth issue was to determine factors affecting indoor air quality and propose guidelines for IAQ. In Chapter 4, guidelines are given for IAQ which provide reference points for assessing the extent of remedial measures in buildings.

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 preexisting disease in children. The guidelines developed for residential buildings by a Working Group of the Federal/Provincial Advisory Committee on Environmental and Occupational Health (see Chapter 4) appear to be stringent enough to protect the health of adult office workers as well as school children, hence the recommendation for its adoption.

The sixth issue was to recommend remedial measures for IAQ problems. Adequate fresh air supply appears to be the single most effective solution to IAQ problems both in office buildings and schools because the sources of an indoor pollutant in most cases cannot be avoided or reduced. Properly filtered, air free from CO_2, bacteria and tobacco smoke, is the primary means of control of air contaminants in occupied spaces.

ASHRAE Standard 62-81R prescribes the rates of outdoor air intake to achieve acceptable IAQ. The Committee has reviewed and accepted these rates as sufficient to dilute contaminants that are generated internally to acceptable levels. These prescribed rates correspond to the MOL and MGS experience, especially where these rates control CO_2 to a concentration of 1,000 ppm or less. CO_2 is used as a surrogate measure for other contaminants including odours.

The seventh issue was second-hand smoke exposure. This topic has captured public attention over the past several years. The most serious health hazard is demonstrated by the fact that second-hand smoke exposure, in an office where many people smoke, is equivalent to 1-5 cigarettes per day and that approximately 5,000 persons in the U.S.A. die annually from lung cancer caused by exposure to second-hand cigarette smoke. Children exposed to second-hand smoke have been shown to have an increase in respiratory illness. Nevertheless, no one satisfactory method is available to measure the amount of cigarette smoke present in a workplace.

1.2 Definitions

Indoor Air Quality (IAQ):
IAQ refers to the physical, chemical and biological characteristics of indoor air in non-residential workplaces with no internal industrial processes or operations, which can affect the comfort or health of the occupant.

Tight Building Syndrome (TBS):
TBS refers to non-specific symptoms of discomfort and ill-health, such as eye, nose and throat irritation, mental fatigue, headaches, unspecific hypersensitivities and other similar complaints, in a significant number of occupants of non-industrial workplaces (mainly offices with HVAC systems). The causes of IAQ complaints are hard to identify for many reasons (e.g., biological exposure, chemical exposure, physical exposure, psychological aspects, etc.).

Health:
Health refers to a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.

1.3 Population at Risk

The Committee derived a list of those buildings and offices in which the working population may encounter IAQ problems. This list is given in Table 4.5 of Chapter 4. The list is based on the Ministries' experience and by no means is all inclusive. Building types are subdivided in the list and the groupings are based on the nature of the occupancy.

1.4 Cost Implications

This report does not address the capital and operating costs of introducing recommended amounts of outdoor air into non-residential buildings. The committee did not consider this to be part of their terms of reference.

However, the Committee would like to refer the readers to a conclusion of the Federal-Provincial Working Group on Indoor Air Quality which was contained in their first report to the Advisory Committee on Environmental and Occupational Health. According to the Group, implementing their recommended ventilation requirements for offices will have minimal energy cost implications for large offices. Also, it should be possible to provide 20cfm (cubic feet per minute) of ventilation for each person without significant building modifications. As far as schools and especially portables are concerned, no similar energy cost estimates are available in the published literature.

CHAPTER 2

HEALTH EFFECTS OF INDOOR AIR POLLUTANTS

Indoor air complaints are now recognized as health concerns. Since people spend about 70 to 90% of their time indoors, this issue is significant. The very young, elderly and infirm spend even more time indoors.

2.1 Definition of "Health" Used in the Development of the Protocol

In seeking a guiding definition of health, the Committee considered the concepts used by the leading standard-setting organizations.

First of all, the Oxford dictionary defines "health" as "soundness, (i.e. not diseased or injured) of the body". This definition was rejected as relying too much on physical injury, an unlikely consequence of the tight building syndrome.

In developing guidelines for domestic residences, the Federal Provincial Advisory Committee on Environmental and Occupational Health used the following definition:

> "Air within domestic premises should be sufficiently free from biological, physical and chemical contaminants to ensure that there is negligible risk to the health and safety of the occupants."

However, the Committee believed that in investigating indoor air quality complaints, it has become apparent that concentrations of contaminants are often low, so that the symptoms of the persons exposed are more related to comfort than to health. Comfort complaints are important, however, in that these have a significant adverse effect on worker morale and productivity.

The Committee then examined the World Health Organization's definition of health which is:

> "A state of complete physical, mental and social well-being and not merely the absence of disease or infirmity."

This definition was adopted as it allows the setting of indoor air quality guidelines based on "comfort" and "health".

2.2 Health symptoms associated with Tight Building Syndrome (TBS)

Symptoms commonly associated with the tight building syndrome are: headache, dizziness, eye and upper respiratory irritation, skin rashes and irritation, shortness of breath, nausea and fatigue. Unfortunately, these symptoms are general or subjective and may be indicative of many other medical conditions. For example, when investigating incidents of carbon monoxide intoxication at ice

arenas, the Ministry of Health has noted that the symptoms of headache and nausea were often ascribed to food poisoning (ODSR, 1986). Indoor air quality complaints are commonly ascribed to influenza, viral infections or psychosomatic illness.

Perhaps the best indicator that work place exposure may play a role in the symptoms reported by an individual, is the observation that the symptoms disappear shortly after leaving work. Another good indicator is the observation that the symptoms worsen during the work day, typically peaking after lunch about 2 p.m. The latter is suggestive of a contaminant accumulating due to increased human activity in the work place.

There are many reasons why the causes of reported health symptoms are difficult to determine:

(1) The concentrations of contaminants, when measured, have often been found to be low, often many times lower than the corresponding industrial standards.

(2) The concentrations of the contaminants may be intermittent. For instance, elevated concentrations of methanol would occur only when the spirit duplicator is used in a given work setting (e.g. schools). Thus, complaints of headache and dizziness would occur only on those days and times when the duplicator is used.

(3) The concentrations of the contaminant may be due to a single, non-repeatable event. For instance, incidents of severe upper respiratory irritation have been reported due to particles of carpet detergent, after recent cleaning in a workplace.

(4) There is a wide variation in individual susceptibility based on genetics, age, medication, and previous exposures to pollutants. Certain groups may be more sensitive, e.g. young children, pregnant women and the elderly are more susceptible to the toxic effects of carbon monoxide. Certain persons may be affected more seriously because of aggravation of pre-existing medical conditions, for instance, if they already have allergies.

(5) Many chemicals have synergistic effects that are often unknown and difficult to predict. Tobacco smoke is known to act synergistically with a number of contaminants. From industry, it is well known that tobacco smoke can potentiate the carcinogenic effects of substances such as asbestos.

(6) Physical factors (temperature, humidity, noise, etc.) may place added stress on the body and are often not considered to be a cause of health symptoms.

Considerable research since 1980 has identified a number of contaminants as the cause of indoor air quality complaints. These chemical and biological agents are discussed in detail in the following section.

Indoor air quality complaints occasionally have a psychogenic component. Employers fear that dissatisfied workers may complain that the workplace air is affecting their health as this is an "acceptable" form of causing trouble. Often, however, such complaints are due to the difficulty in finding the source of indoor air pollution and thus in rectifying the problem.

If an indoor air problem is ignored, workers may ascribe all manner of ills, such as birth defects to it with a significant deterioration in worker productivity and morale. Such a case was investigated by the Ministry of Health at North York City Hall. The cause of the problem was trivial - bad odours from an improperly disinfected humidifier - but the anxiety amongst employees was considerable and had disrupted work for over two years.

There is no question that some complaints are founded in mass hysteria, but it is recommended that all probable causes be investigated first before arriving at this conclusion (Alexander, 1986; Boxer, 1985).

Typical symptoms of psychosomatic illness include headaches, nausea, dizziness, fainting, anxiety and breathlessness due to hyperventilation.

2.3 Causative Agents

2.3.1 Physical Agents

Physical agents are discussed in Chapter 3 on "comfort". Typical tight building syndrome (TBS) symptoms are reported with regard to temperature, humidity, noise and so forth and are summarized in Table 2.1.

2.3.2 Chemical Agents

Several chemical agents have been identified as the cause of indoor air quality complaints. The most significant ones are listed in Table 2.2 (at end of chapter), together with common sources of these compounds, and their associated reported health symptoms (Wesolowski, 1984, Squirrell, 1984).

Many effects are transient and do not have long term implications for health. Serious health effects can be caused by chemicals such as carbon monoxide, asbestos, formaldehyde, and pesticides.

Every year in Ontario, people die as a result of carbon monoxide poisoning. It is also a cause of "outbreaks" in ice arenas or in offices situated in close proximity to improperly vented parking garages. Carbon monoxide gas is a particularly insidious poison in that it is colourless, odourless and tasteless. At lower concentrations, typical symptoms are headache and nausea. At higher concentrations, death or permanent brain damage may be the

Table 2.1

CAUSE	HEALTH SYMPTOMS REPORTED	COMMENTS
Temperature greater than 25°C	fatigue, headache, stuffiness	
Temperature less than 18°C	chills, "flu like" symptoms	
Humidity greater than 80%	fatigue, stuffiness, headache, dizziness	effects potentiated if air temperature is also high
Humidity less than 20%	headache, eye irritation, nose bleeds, dry throat, exacerbation of cold and flu symptoms	
Noise greater than 70dB	lack of concentration, headache, stress-related symptoms	
Infrasound (low frequency vibrations)	nausea	

result. Children and pregnant women are more susceptible to its effects.

Asbestos is a recognized human carcinogen. This family of crystalline silicate minerals has caused a variety of serious illnesses in exposed workers: lung cancer, asbestosis, mesothelioma (a cancer of the pleura), and possibly gastrointestinal cancer. A few years ago, there was great concern about the presence of asbestos in Ontario schools and the Ministry of Education conducted a remedial program for removal or encapsulation. Because of the long latency period of the diseases caused by asbestos (20-40 years), there was great concern that school children might develop these illnesses in young adulthood. Experience has shown, however, that removal of asbestos may actually increase risk of exposure and that management of the situation must be undertaken under the advice of experienced industrial hygienists.

Formaldehyde is a colourless gas with a sharp, pungent odour. It is extremely irritating to the eyes and upper respiratory tract and is an animal carcinogen. Formaldehyde gas is a breakdown product of urea formaldehyde insulation or UFFI, which was the subject of a removal program sponsored by Health and Welfare Canada in the early 1980's. It has also been shown to be emitted from wall board, plywood and furnishings (Walkinshaw, 1988).

Pesticides have been reported to be associated with outbreaks of poisoning. In many of these cases, the people were unaware that the indoor environment had been treated with a pesticide (White et al, 1987). It is essential that when premises are treated, occupants are informed and proper procedures and precautions be taken by the pesticide operators to avoid excessive application and inadvertent exposure of building occupants.

Cigarette smoke, an indoor contaminant of significant health concern, is discussed in detail later.

2.3.3 Microbiological Agents

Microbiological agents have recently been recognized as a significant cause of indoor air pollution. Most often the source is an improperly maintained heating, ventilation and air conditioning (HVAC) system, particularly the humidification component. There are also reports of fungal contamination of rugs and furnishings following flooding of an office environment with consequent upper respiratory symptoms reported in employees (Hodgson et al 1985; Youle, 1986).

Odour problems may also be due to microbiological contamination. In investigating complaints of odours at North York City Hall, the Ministry of Health found evidence of Penicillium and Alternaria molds in the HVAC system. Overgrowth of molds and fungi in the HVAC system have, on occasion, rendered office buildings uninhabitable and clean up can be next to impossible (Tennessee Valley Authority, 1983).

Legionnaire's disease is a bacteriologic pneumonia caused by the agent Legionella pneumophila. Symptoms include fever, chills, chest pain, diarrhea, malaise and myalgia. Immunocompromised persons are particularly susceptible and at greater risk of death from this disease. Legionella have been found in the cooling towers, shower heads and water systems of many buildings, including hospitals (Godish, 1986).

Many agents have been implicated as the cause of "humidifier fever", a hypersensitivity pneumonitis with symptoms of fever, chills, tightness in the chest, cough, breathlessness and malaise (McLellan, 1983). Skin irritation and dermatitis have also been reported. Although research remains to be done to determine the precise etiology of these illnesses, microorganisms considered to be of concern include but are not limited to the following (Health and Welfare Canada, 1987; Ager, 1983):

o	Thermoactinomyces spp.	
o	Acanthamoeba polyphaga	(protozoa)
o	Aspergillus spp.	(fungi)
o	Aureobasidium	"
o	Penicillium spp.	"
o	Pseudomonas spp.	(bacteria)
o	Flavobacteria	"
o	Legionella	"

It has also been suggested that non-viable spores, mycotoxins, endotoxins and submicron particulate antigens can be associated with respiratory illness (ACGIH, 1986). Individuals with asthma can have their medical condition aggravated by the presence of molds, mites, pollen, algae, insects, animal danders, bird (especially pigeon) droppings, and so forth (Hosein, 1987).

2.4 The Problem of Stale Air

Probably the most common complaint received about indoor air quality is that of "stale air". Typical symptoms of headache, stuffiness, upper respiratory tract irritation, drowsiness, lethargy and fatigue are reported. These symptoms tend to worsen during the course of the day, peaking in the early afternoon, then disappearing after departure from the building.

Lack of air movement in buildings with a full air handling system is another common reason for complaints. The combination of elevated temperature and unequal air movement is frequently confused with the presence of pollutants in the atmosphere. The reverse can also be true, namely that cool air moving too quickly is perceived as unhealthy. Thus building HVAC systems must be monitored constantly.

Investigators with the Ministry of Labour have demonstrated an association between complaints of "stale air" and elevated levels of carbon dioxide (CO_2) in the workplace, using CO_2 as a marker

for insufficient fresh air supply. The associations observed are summarized in Table 2.3 (Rajhans, 1983).

Table 2.3
Association of TBS Symptoms with Concentrations of Carbon Dioxide in the Workplace

CONCENTRATION OF CO_2	SYMPTOMS REPORTED
Less than 600 ppm	none
600 - 1000 ppm	occasional complaints of headache, drowsiness, stuffiness, etc.
greater than 1000 ppm	above complaints general

CO_2 is not the sole cause of these complaints because adverse health effects associated with elevated levels of CO_2 have not been reported for levels less than 7,000 ppm. CO_2 is used as a surrogate measure for other contaminants including some particulates and odors that may build up due to the lack of adequate fresh air supply. This build up, together with physical factors such as air temperature and humidity, act to produce the reported health symptoms. Thus, elevated levels of CO_2 especially greater than 1000 ppm, function as an <u>indicator</u> that ventilation should be improved. More research on the cause of the health symptoms reported in relation to stale air would be helpful (FPACEOH, 1986).

2.5 Second Hand Cigarette Smoke

Cigarette smoke is a complex mixture of several hundred substances: irritants (aldehydes), toxic chemicals (carbon monoxide); and carcinogens (benzo (a) pyrenes, tars, etc.). Over 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. Irritant 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 second hand 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 or at work or both. The ambient concentrations of second hand 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, second hand exposure is equivalent to 1-5 cigarettes per day (House, 1985). Statistical analyses have been conducted to predict that approximately 5000 persons in the U.S.A. die annually from lung cancer caused by exposure to second hand cigarette smoke (Repace, 1982).

To date, no one satisfactory method is available to measure the amount of cigarette smoke present in a work place. Concentrations of carbon monoxide are sometimes used as an indicator of irritation complaints. Other more specific pollutants (such as nicotine, 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 second hand 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).

TABLE 2.2

Chemical Agent	Source	Symptoms	Comments
Carbon Monoxide	automobile exhaust, ice resurfacers, propane refrigerators, furnaces, kerosene heaters, tobacco smoke	mild - headache, nausea, breathlessness, dizziness, fatigue severe - cherry red lips, visual disturbances, cyanosis, mental confusion, angina, coma and death	Lethal dose is 1000 ppm. Severe poisoning may have irreversible effects on the CNS system.
Formaldehyde	off gassing of wood products (plywood and particle board) and furnishings, UFFI, tobacco smoke	eye and upper respiratory tract irritation	Odour is apparent at levels of 1 ppm or less. Animal carcinogen allergic sensitizer.
Nitrogen Oxides	combustion processes, gas stoves, kerosene heaters, diesel engines, tobacco smoke	mild - eye and upper respiratory irritant severe - pulmonary edema	Persons with chronic lung conditions are more susceptible.
Ozone	photocopiers, electrostatic air cleaners	eye and respiratory irritation, headache, breathlessness, cough	Pungent odour is apparent at concentrations above potentially harmful levels
Total Volatile Organic Compounds (VOC's)	off gassing of furniture, solvents used in the workplace, cleaners, personal care products, tobacco smoke, newly installed carpets, photocopiers	headache, dizziness, upper respiratory tract irritation, nausea	

Table 2.2(cont'd)

Chemical Agent	Source	Symptoms	Comments
Sulfur Dioxide	combustion processes, kerosene heater	upper resiratory tract irritation	Elderly and persons with cardiopulmonary disease more susceptible.
Respirable particulates	paper, dust, soil from daily activity, fibreglass insulation in duct work, tobacco smoke	Eye and upper respiratory irritation, allergic reactions (?)	
Pesticides	workplace treated for pest removal, consumer products	mild - headache, fatigue, dizziness, weakness, nervousness, nausea, perspiration, upper respiratory irritation severe - nausea, trembling, constriction of pupils, visual disturbances, breathlessness, convulsions, unconsciousness	Symptoms may vary according to the type of pesticide and the exposure.
Methanol	spirit duplicators	headaches, dizziness, nausea	
Sodium Dodecyl Sulfate	carpet shampoos	eye and upper respiratory irritation	Effects diminish with time.
Asbestos	building insulation and fireproofing, acoustical tiles	no acute effects noted	Human carcinogen.

Table 2.2(cont'd)

Chemical Agent	Source	Symptoms	Comments
Ammonia	cleaning compounds, blueprint copiers, ice arenas	severe eye and upper respiratory tract irritation, pulmonary edema	
Polychlorinated Biphenyls	malfunctioning fluorescent lights, transformers	mild - eye and upper respiratory tract irritation severe - chloracne, liver damage	

CHAPTER 3

COMFORT FACTORS

Comfort factors can play a role in how people perceive the indoor environment. These factors include thermal comfort, lighting, and noise.

3.1 Thermal Comfort

Thermal comfort is defined as the state of mind in which a person feels satisfaction with their thermal environment. A person experiencing thermal comfort feels thermally neutral for the body as a whole. In simpler terms, occupants will express dissatisfaction with their thermal environment by stating that it is too warm or too cool. However, a person experiencing thermal neutrality for the body as a whole may experience local discomfort if one part of the body is warm and another cold. Local thermal discomfort can be caused by drafts, contact with warm or cold surfaces like the floor, or vertical air temperature gradients, etc.

In offices and other work places where activity is fairly light, where people are sitting, standing or moving around without carrying heavy loads, the thermal environment plays a major role in creating an acceptable indoor environment. However, the extent of the relationship between IAQ complaints and symptoms, and deficiencies in thermal comfort, is not known. The thermal comfort of a human being is not only a function of air temperature, but also of other less obvious parameters.

Satisfaction with the thermal environment can be described by four environmental and two occupant parameters. These are air temperature, mean radiant temperature, relative air velocity, humidity, occupant activity level, and occupant clothing thermal resistance.

A person's activity level can be expressed in terms of their metabolic heat production, its transfer to the environment and the resulting physiological adjustments and body temperatures. Thermal sensations can be described by feelings of hot, warm, slightly warm, neutral, slightly cool, cool and cold. A considerable amount of laboratory and field research has been conducted in order to describe the thermo-regulatory system of the human being as well as the environmental parameters influencing the heat balance of an individual.

For each person there exists an interval of ambient temperatures or "comfort zone" within which they will feel reasonably comfortable. Comfort zones will vary from person to person. Studies have shown that the preferred comfort conditions for an individual will vary only slightly from day to day. It has also been found that the young and the elderly prefer the same thermal environment.

3.1.1 Thermal Standards

Guidelines have been established by ASHRAE (Standard 55-1981) in order to provide guidance in designing and maintaining suitable indoor thermal environments. The aim of these requirements is to define a thermal environment which is acceptable for at least 80% of the occupants.

ASHRAE recommends temperature ranges of 19.5 to 24.6°C in winter and 22.2 to 27.2°C in summer. Comfort zones at different temperatures and humidities are presented in Figure 3.1 at the end of the chapter.

ASHRAE also suggests limits on humidity and air movement. The dew point temperature should not be less than 1.7°C or greater than 16.7°C. The thermal effect of humidity on the comfort of sedentary people is small. The upper and lower dew point limits are based on considerations of comfort, respiratory health, mold growth and other moisture related phenomena.

The average air movement in the occupied zone for the winter period should not exceed 0.15 m/s (30 fpm). The average summer air movement in the occupied zone should not exceed 0.25 m/s (50 fpm). However, the comfort zone may be extended to 28°C from 26°C by increasing average air movement to a limit of 0.8 m/s (160 fpm).

As previously mentioned, these guidelines have been set to provide a thermal environment which is acceptable for at least 80% of the occupants. That means that even if the requirements are met there may still be persons who are not satisfied with the thermal environment. In every group of people there always exist some persons who are very sensitive regarding the thermal environment.

3.2 Odour

Odours or any factor which evokes a sensory response, such as temperature or humidity are most likely to cause complaints. More potentially hazardous substances would not concern people unless they knew of their presence. In the outdoor environment, over half of the complaints received by appropriate authorities relate to odours.

Factors which may be responsible for odours in offices include those which originate from cooking, solvents, outdoor air pollutants, humidifiers and tobacco smoking (see Table 3.1 at end of chapter).

A common odour, such as from cooking, will usually cause little adverse reaction. But anything which has an unfamiliar or unknown origin will be very likely to evoke concern. On the other hand, non-smokers are becoming increasingly reluctant to accept tobacco smoke partly because of its odour.

Another factor associated with odour is persistence. Odours which remain in any given location are likely to be more objectionable. Such odours are usually caused by compounds which attach themselves easily to materials such as clothing and furnishings.

3.3 Lighting

Where work space is used mainly to support specific visual tasks, as in offices, the quantity and quality of lighting can have a major influence on the efficiency with which tasks are carried out and on the comfort and well-being of the worker. Lighting is also important for purposes of safe access, movement and egress.

The quantity of light per unit area in a space is referred to as illuminance, and is measured in lumens per square meter or lux using a simple light meter. Recommended illumination levels for various environments and tasks are given in Table 3.2.

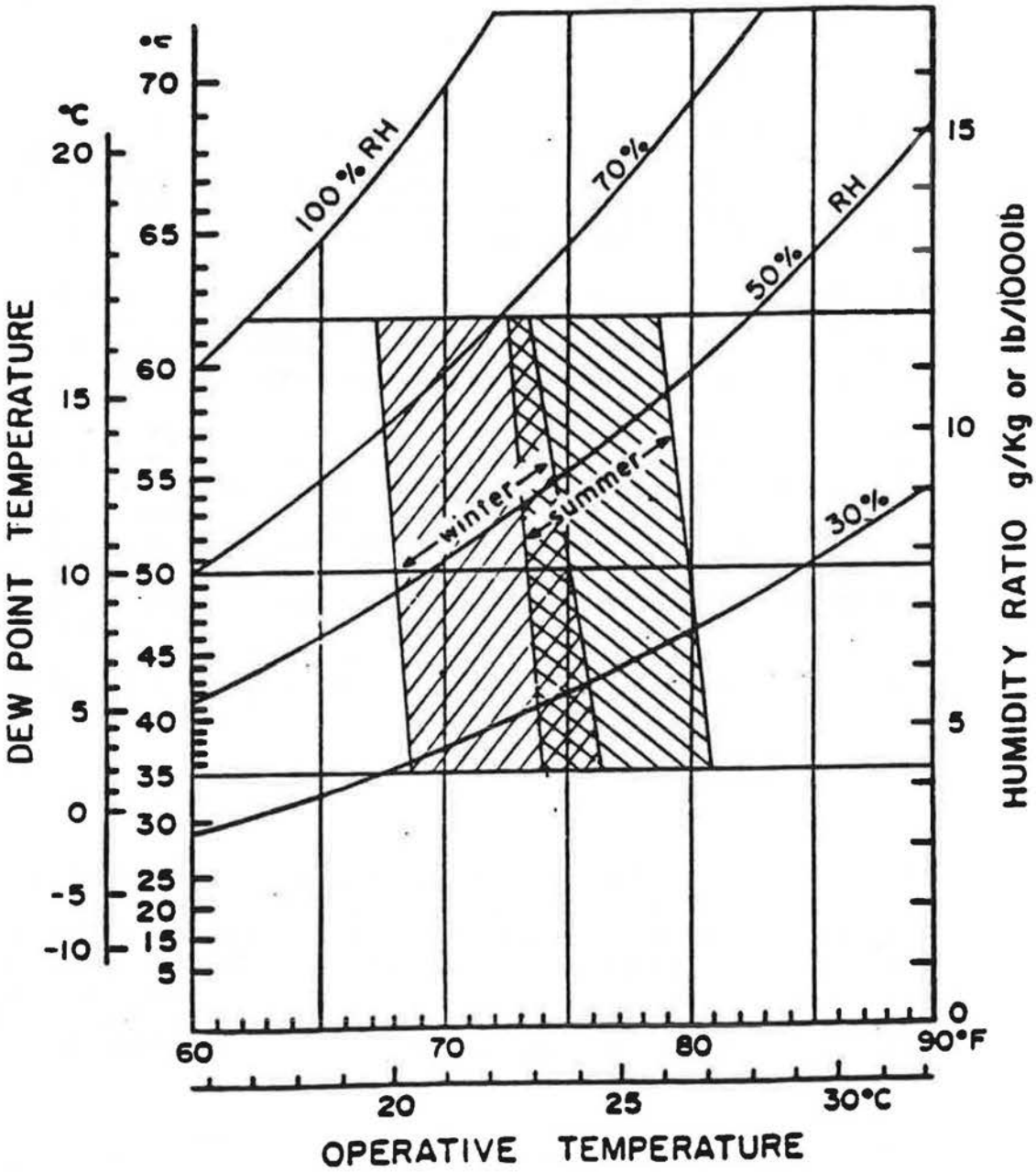
The quality of lighting is more important than its quantity. Poor lighting can cause worker discomfort, stress and other adverse physiological reactions. The resulting stress may cause psychological problems similar to those arising from poor indoor air quality. In diagnosing and solving IAQ problems, it is desirable to ensure that the lighting conditions are not a major cause of complaints. Determining lighting quality is a sophisticated undertaking, because quality is composed of brightness, contrast, glare, specular reflection, and colour. These criteria are also dependent upon the nature of the task, and to some extent, on the characteristics of the worker, such as age.

3.4 Noise

Aural quality refers to the acceptability of the acoustic conditions of the indoor environment from the standpoint of the health and comfort of the occupants. Hearing damage and other physiological problems can result from the cumulative effect of continuous high noise levels or short duration noise peaks. However, general noise levels in office environments are almost certain to be less than allowable values related to noise induced hearing loss.

Complaints often occur in open-plan offices about lack of speech privacy. The resulting stress might cause problems similar to those arising from poor IAQ.

Figure 3.1
ASHRAE Comfort Zones



ASHRAE Comfort Chart: Acceptable ranges of temperature and humidity for persons clothed in typical summer and winter clothing, and at light, mainly sedentary activity.

SOURCE: ASHRAE Standard 55-1981. Thermal Environmental Conditions for Human Occupancy.

Table 3.1

Table of Odours Which can Occur in Office Buildings

POSSIBLE DESCRIPTIONS OF THE ODOUR	PROBLEM INDICATED	OTHER INDICATORS OF OF THIS PROBLEM
auto exhaust, diesel fumes, furnace room smell, the heating system kitchen exhaust	carbon monoxide	symptoms: headaches, nausea, dizziness, tiredness
body odour	carbon dioxide	symptoms: headaches and tiredness, complaints of lack of air, stagnant air, stuffiness
(wet) cement, (wet) plaster, dusty smell, chalky smell	particulates (from humidifier)	hard water in this area, spray humidifiers uses, white dust on diffusers
mouldy	biological	mould may be visible, symptoms of allergy
solvent smell, chemical smell	VOC	presence of chemicals, or products containing them, symptoms of allergy
chemical smell, like formalin	formaldehyde	eye irritation, nose and throat irritation, presence of unpainted pressed wood products

SOURCE: Public Works Canada, Building Performance Division. Indoor Air Quality Test Kit: User Manual. 1988.

Table 3.2

Recommended Illuminances

Classroom;	
Kindergarten[1]	350 lux
General classrooms, seminar rooms	500 lux
Visually impaired students	1500 lux
Large group instruction areas (including lecture theatres)[2]	250 lux
Auditorium;	
Assemblies only[2]	250 lux
When used for study or examinations	500 lux
Cafeteria;	
General	250 lux
Servery	350 lux
Kitchen	500 lux
When used for study or examinations	500 lux
Drafting;	
General	500 lux
On boards[3]	1000 lux
Graphic arts;	
General	500 lux
On boards[3]	1000 lux
Gymnasium; (Gymnatorium and Cafetorium)	
General	250 lux
When used for study or examinations	500 lux
Laboratories;	
General	500 lux
Demonstrators' desks	750 lux
Library;	
Stacks (with little local reading)	250 lux
Reading, note taking, cataloguing	500 lux
Seminar rooms	500 lux
Offices	500 lux
Music room	500 lux
Sewing[3]	500 lux
Shops[3]	500 lux

Table 3.2 cont'd.

Typing	500 lux
Washrooms and locker areas	250 lux
Corridors;	
With lockers	250 lux
Without lockers[3]	100 lux
Mechanical and service areas	250 lux
Storage areas	100 lux

Notes:
1. The illuminance of 350 lux has been selected for the kindergarten since the visual tasks are not severe.

2. It should be possible by simple switching to vary the illuminance by 50% either up or down to accommodate note taking or audio-visual presentations. Total control by areas is desirable.

3. Local lighting may be used to supplement the general lighting where fine work is to be carried out or feature displays are located. Supplementary lighting is frequently provided for chalkboards. Since study carrels cut off light from the overhead general lighting system, a local lighting luminaire in each carrel is frequently desirable.

SOURCE: Ministry of Education. Lighting for Education. 1981.

CHAPTER 4

DERIVATION OF INDOOR AIR QUALITY GUIDELINES AND STANDARDS FOR NON-INDUSTRIAL WORKPLACES

4.1 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, whether 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 micro-organisms and allergens); and
- those given off by the "construction materials and finishes and the furnishings" used in the building.

The concentrations of contaminants in the first three categories will vary with amount of human activity. Those in the fourth category are likely 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 source of poor indoor air quality appears to be 1) inadequate ventilation (50% to 70% of cases investigated), followed by 2) contamination from inside the building, 3) contamination from outside the building, 4) microbiological contamination and 5) contamination from the building fabric (NIOSH, 1987; Collett and Sterling, 1988).

A summary of indoor pollutants, emission sources and concentrations are shown in Table 4.1 (Spengler and Sexton, 1983) and in Fig. 4.1 (Nero, 1988) at the end of the chapter. The indoor concentrations are generally higher than the outdoor concentrations, because the indoor sources emit to a confined volume of air and therefore the dilution is small. For example, the U.S. EPA Team study (Wallace, 1987), found that personal air exposures for eleven 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. There was also considerable variability in the concentrations of several chemicals 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 side-stream 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 aggravating the conditions of people with pre-existing disease, including heart disease, lung disease and allergies to other substances, to cancer, chiefly of the lung 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 in 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).

4.2 Existing Standards and Guidelines

The symptoms and complaints associated with indoor air quality problems are generally non-specific 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 odour. Generally, the causes are multi-factorial and it has, in general, not 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 non-industrial workplace to protect workers.

Two groups that have been active in the field of setting indoor air quality guidelines are the World Health Organization (WHO) and the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE). Their approaches to this problem 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 non-industrial and non-residential buildings.

4.2.1 Ventilation

ASHRAE produces and maintains ventilation standards which are used in most North American non-industrial buildings. The standards, which are in the process of being updated, provide heating, ventilation 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 which will maintain indoor air pollutants below specified levels.

The existing ASHRAE Standard 62-1981 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 (ASHRAE, 1981).

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 an alternative to using the minimum prescribed outdoor air supply are given in Table 4.2.

The carbon dioxide limit is recommended as a surrogate measure for the lack of fresh air supply and odour 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 their investigations into indoor air quality problems, that carbon dioxide levels can be related to the frequency of occupant complaints. MOL's findings are given in Table 4.3, together with the equivalent air supply (Rajhans, 1985). 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 4.4.

Table 4.5 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 Building Code.

4.2.2 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 which is accepted for work places and occupational exposures where chemicals are routinely used would be unacceptable for residential, office or retail spaces. Therefore, occupational standards, for example threshold limit values proposed by organizations such as ACGIH, MOL or OSHA, are not relevant measures of indoor air quality in non-industrial settings.

The Federal/Provincial Advisory Committee on Environmental and Occupational Health also reject the use of occupational limits for setting indoor air quality levels in non-industrial buildings (HWC, 1987).

ASHRAE (1986) points out that, as a preliminary guideline for non-industrial indoor spaces, it was customary 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 give in Table 4.6.

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 4.7.

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 non-industrial 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 are not intended to apply to other environments such as offices or industrial workplaces where other

factors, such as multiple occupancy, may be important (Armstrong et al, 1985), it appears perverse to accept indoor air quality guidelines for offices that differ from those for residences. The residential guidelines were developed to protect a person's health over a lifetime, and as such, can logically include the office in addition to the home environment.

The Working Group selected 17 substances or groups of substances for detailed review because of their potential to cause adverse health effects and their possible presence indoors. Guidelines, expressed in terms of concentration ranges, were developed for 9 of these (group A). For the others (group B), it was not possible to derive quantitative guidelines because the database was inadequate or because human exposure limits were deemed inappropriate. However, wherever possible, recommendations were made on measures to control indoor exposure to the group B contaminants. In developing the guidelines, especially for those for which actual concentration levels are given, the Working Group looked at 1) long term exposures to low levels of pollutants, and 2) possible excursions in pollutant levels due to intermittent release from sources.

The two groups examined by the Working Group encompassed the following substances:

A. Those with definite guidelines:

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

B. Those for which only recommendations can be given at this point:

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

For the first group, two types of exposure limits were derived:

1. the acceptable long term exposure range (ALTER) is 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.

2. the acceptable short term exposure range (ASTER) is 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 Working Group took into account, wherever possible, the potential for the possibility of interactive effects, since many contaminants are likely to be simultaneously present in indoor air. However, in most cases there was insufficient data to address this problem.

The Working Group critically reviewed the available literature and outlined the rationale for the guidelines. The Group plans to publish a detailed account of the scientific criteria and reference materials. The Working Group also recognized that their list of chemicals did not fully represent the compounds found in indoor air. As new data becomes available, exposure guidelines for additional contaminants or groups of contaminants are to be prepared and the existing guidelines revised.

The exposure guidelines are summarized in Table 4.8. In deriving the guidelines, the Working Group looked for a quantitative relation between a pollutant and its effects. Such quantitative relationships are difficult to determine precisely from epidemiological studies (studies of human populations) because of weaknesses, such as confounding variables and poor estimates of exposure. Clinical studies on humans, although the exposure can be controlled, are limited to temporary and short term effects.

Animal studies, though useful, are carried out at high exposure levels and have the problem or uncertainty of extrapolation from high concentrations to low concentrations, and of extrapolation from effects in animals to effects in humans. Nevertheless, the Working Group felt that clinical and epidemiological studies, combined with animal studies, provided substantial quantitative information on the effects of exposure to a given pollutant.

For non-carcinogenic substances, the Working Group used the approach of threshold level - a level of exposure below which there are no apparent detrimental effects - divided by a safety factor. The choice of a safety factor is based on a consensus decision by experts, and strictly has no scientifically defensible basis. For some substances, the Working Group used a safety factor of 2, which has also been used by the World Health Organization. Where there was sufficient data from reliable clinical studies of transient health effects, no safety factor was incorporated in the derivation of a short time exposure guideline. Because of the wide variation in the susceptibility of individuals to irritants, notably aldehydes, short term exposure guidelines were derived by applying a factor of 5 to the lowest value reported to cause a significant increase in symptoms of irritation. The Working Group felt that the use of occupational hygiene limits was indefensible without a thorough knowledge of their scientific bases.

For carcinogenic substances, there is evidence that threshold levels may not exist. Thus there is apparently no level of exposure at which a hazard does not exist, although at very low concentrations the health risks may be so small as to be

undetectable. Therefore the use of a threshold level and a safety factor was considered to be not appropriate for carcinogens.

Ideally, exposure to known or suspected carcinogens should be avoided. Formaldehyde is a suspected human carcinogen, and the maximum concentrations listed in Table 4.8 are the lowest levels that are practical to achieve and at which there is no undue public health risk. In deriving the long term exposure guideline for formaldehyde, a mathematical model was used to extrapolate to very low exposure levels and included information on the mechanism of action. Nevertheless, the calculated risk at low levels of exposure are probably overestimated due to the conservative assumptions on which the mathematical model was based.

A comparison of the exposure ranges in Table 4.8 and the WHO (Table 4.7) and ASHRAE numbers (Table 4.2) is not entirely valid as the exposure times are different. Nevertheless, the concentrations in the three tables are quite close.

For the second group of substances, that is, those 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 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 aerosols 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 fibres such as fibreglass, mineral wool and ceramic fibres. 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".

4.2.3 Outdoor Contamination

Assuming adequate ventilation and no indoor sources of contaminants and adequate ventilation, the indoor air quality will ultimately be 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 intakes to the HVAC, give rise to elevated concentrations.

Table 4.9 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.

4.2.4 Biological Contamination

Bioaerosols include viable micro-organisms (bacteria, fungi, algae, mites, viruses) and non-viable 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 matters 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 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 1×10^5 colony forming units (CFU)/L in stagnant water or slime.
- Levels of fungi in excess of 1×10^6 CFU/g in HVAC system dust.

There are as yet no guidelines for bioaerosols. However, a level of 1000 CFU/m^3 for viable microorganisms in indoor air has been suggested as a guideline in the literature, although cases of hypersensitivity pneumonitis have occurred at levels below this guideline.

Walkinshaw (1988) quotes a study of fungi in Canadian houses during the winter. Forty-two species were identified; some of them pathogenic. The study proposes the following criteria of acceptability for fungal pollution in indoor air:

- the presence of pathogens and toxigenic fungi should be considered unacceptable;
- more than 50 CFU/m^3 should be reason for concern if there is only one species present;
- less than 150 CFU/m^3 should be considered as acceptable if there is a mixture of species;
- less than 300 CFU/m^3 should be considered as acceptable if the species present are primarily Cladosporium or other common phylloplane fungi.

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
- a high standard of appropriate personal hygiene is maintained".

4.2.5 Contamination from the 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 over long time periods from building materials. 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 over 50 compounds were identified. About 2/3rds 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 chapter 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 allowing new buildings to "degas" until acceptable concentrations are reached, using materials with low chemical release rates, testing and labelling products as to their releases, or isolating such products if used. However, the implementation of such measures will require considerable research as well as the setting of regulations by governments.

4.3 Recommended Guidelines for Indoor Air Quality in Non-Industrial Buildings

There are three stages to achieving acceptable air quality in offices, schools and similar non-industrial 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 1,000 ppm CO_2 (Table 4.3 and 4.4).

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 4.8. Although some jurisdictions may have lower levels, the guidelines in Table 4.8 have been derived after a comprehensive review of the existing knowledge about the compounds.

   (b) The qualitative guidelines in Table 4.10 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 4.7).

4.4 Conclusions

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 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 in the chapter are probably most effectively aimed at avoiding excessive individual exposures rather than 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 identity how source, ventilation and structural characteristics affect indoor air quality.

The control of indoor air pollutants can be achieved through measures such as prescriptions for air ventilation exchange rates, product standards for construction materials and furnishings, restrictions on the use of potentially hazardous materials in products used in offices, certification programs for builders and other trades, public information or a combination of all of these. Spengler and Sexton (1983) give further examples of control measures for air pollutants (Table 4.11).

Guidelines that have been presented in this report for indoor air quality 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).

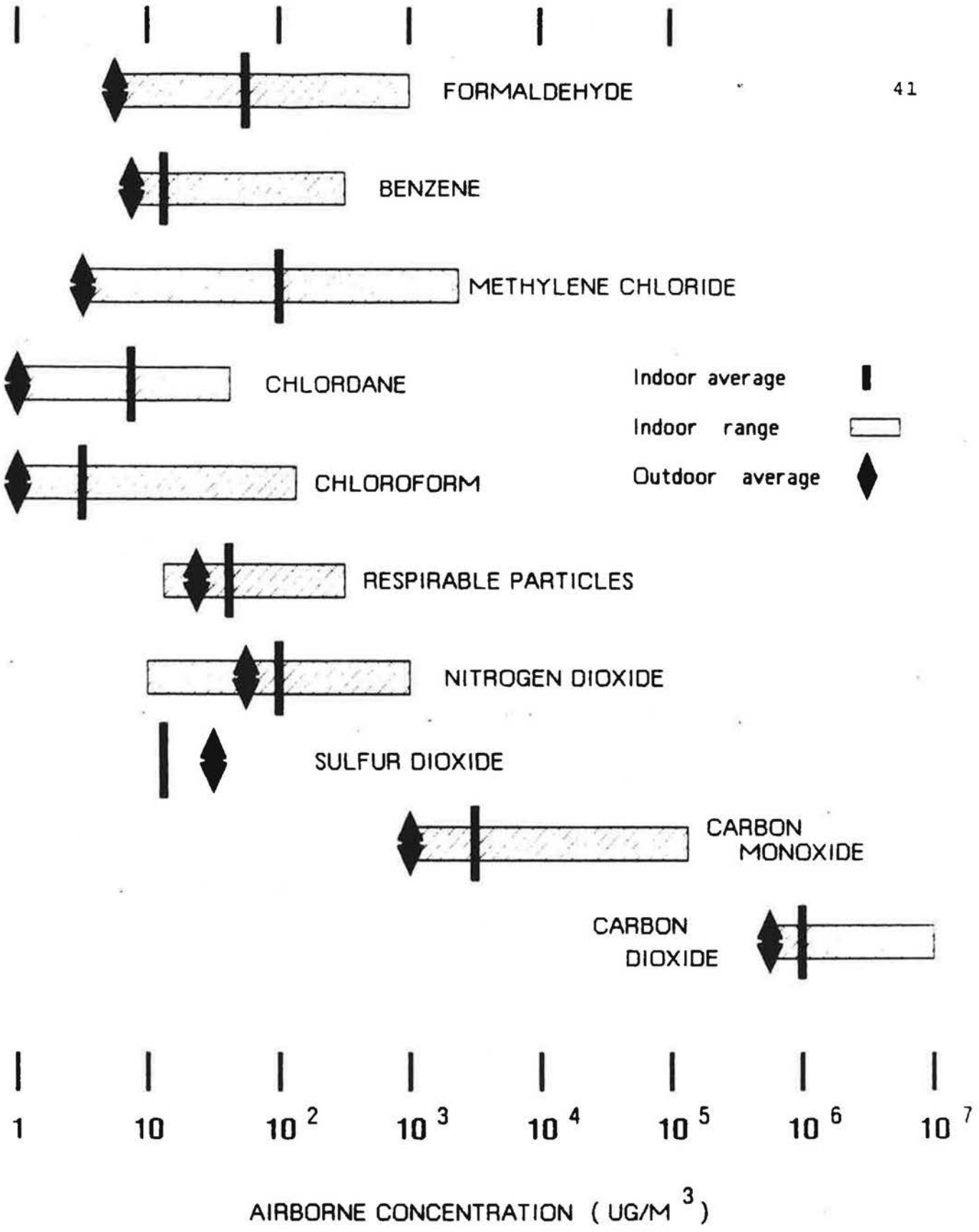


FIG. 4 – 1 . INDOOR AND OUTDOOR AIR CONCENTRATIONS OF SELECTED POLLUTANTS

(SOURCE: Nero, 1988)

Table 4.1
(SOURCE: Spengler and Sexton, 1983)

SUMMARY OF INDOOR POLLLUTANTS, EMISSIONS SOURCES AND CONCENTRATIONS (SPENGLER AND SEXTON, 1983)

Pollutant	Major Emission sources	Typical Indoor Concentrations in the presence of indoor emission sources	Indoor/ Outdoor concen- tration 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

Table 4.1 Cont'd

Pollutant	Major Emission sources	Typical Indoor Concentrations in the presence of indoor emission sources	Indoor/ Outdoor concentration ratio(5)
	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
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

Table 4.2

AIR POLLUTANT CRITERIA IN ASHRAE STANDARDS 62-1981 AND 62-1981

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 4.3

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 4.4

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.

Table 4.5

	Outdoor Air Requirements cfm/person
Assembly Occupancies Intended for the Production and Viewing of the Performing Arts	
Motion picture theatres	15
Opera houses	15
Television studios admitting a viewing audience	15
Theatres, including experimental theatres	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 centres	15
Exhibition halls, other than mercantile occupancies	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

Table 4.5 Cont'd

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

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

Table 4.6

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) 54000 (30,000)	9000 (5000) 54000 (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 4.7

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/m^3
° CO	1-1.5	<2	>5	Indicator for eye irritation (only from passive smoking)
° Nitrosdimethylamine	(1-50) x 10^{-6}	-	-	Mutagens under investigation for carcinogenicity
NO_2	0.05-1	<0.19	>0.32	
CO		2%COHb	3%COHb	99.9%
	1-100	<11	>30	Continuous exposur
Formaldehyde	0.05-2	<0.06	>0.12	Long and short ter
SO_2	0.02-1	<0.5	>1.35	SO_2 alone, short term
CO_2	600-9000	<1800	>12000	Japanese standard 1800 mg/m^3
O_3	0.04-0.4	0.05	0.08	
Asbestos	<10 fibres/m^3	0	10^5 fibre/m^3	For long term exposure
Mineral fibres	<10 fibres/m^3	-	-	Skin irritation

Table 4.7 Cont'd

Pollutant [a]	Concentrations Reported [b]	Concentrations of limited or no concern [b]	Concentrations of concern [b]	Remarks
Organics			(ug/m^3)	
° 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

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 4.8

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	-	<6 300 (<3 500
Carbon Monoxide	Adverse effects on cardiovascular system	(<11) - 8 h ([2]) (<25) - 1 h ([2])	-
Formaldehyde		([3])	([3])
Nitrogen dioxide	Respiratory disease;	<480 (<0.25) - 1 h	<100 (<0.05)
Ozone	Respiratory irritation;	<240 (<0.12) - 1 h	-
Particulate matter ([4])	Impaired lung function	<100 - 1 h	<40
Sulphur Dioxide		<1 000 (<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 ambient pressure.

3 See Aldehydes (total). Since formaldehyde is considered a potential huma 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) a what should be striven for air longer term objectives, given as the targe level 60 ug/m^3 or 0.05 ppm.

4 <2.5 um mass median aerodynamic diameter.

Table 4.9

STANDARDS AND GUIDELINES FOR AMBIENT AIR FOR SELECTED CHEMICALS.

Chemical	Federal [1/] ug/m³ (ppb)	Ontario [2/] ug/m³ (ppb)	US-EPA [3/] ug/m³ (ppb)
Carbon monoxide	0 - 6000 - 8h 6000 - 15000 - 8h	6000 15000 - 8h	10,000 (9000) - 8h
Formaldehyde	---	65(50) 65 - 1h	---
Nitrogen dioxide	---	500 200 - 24h	100 (53) - annual arithmetic mean
Ozone	0 - 30 - 24h 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) - 3h

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 4.10

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 exces humidity and condensation. Keep surfaces clea of dust. Keep stagnant water sources such as humidifier tanks clean, and occasionally disinfect them. Maintain a high standard o personal hygiene.
Consumer Products (chlorinated hydrocarbons, pest control products, product erosols)	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 fibres durin renovations and installation operations. Examine materials an products containing fibres period ically 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 system 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 4.11
(SOURCE: Spengler and Sexton, 1983)

CONTROL MEASURES FOR INDOOR AIR POLLUTANTS

Ventilation: Dilution of indoor air with fresh outdoor air or re-circulated 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; ultra-violet irradiation to decontaminate ventilation air; formaldehyde sorbant filters
Behavioral adjustment: Reduction in human exposure through modification of behaviour 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

CHAPTER 5

PROTOCOL FOR INDOOR AIR QUALITY INVESTIGATIONS

5.1 Introduction

The protocol for IAQ investigations first requires the acquisition of useful information at the least effort and cost. The protocol is based on investigating the building and, if necessary, the symptoms of the workers. Both of these may be needed to identify indoor air problems before remedial measures are applied.

The protocol for IAQ investigations developed by the Committee has four stages:

Stage 1. Preliminary Assessment
Stage 2. Questionnaire
Stage 3. Simple Measurements
Stage 4. Complex Measurements.

In the Preliminary Assessment, physical factors and chemicals and their sources that cause indoor air quality problems may be identified. The Questionnaire amplifies this and provides for the evaluation of workers' responses to poor indoor air quality.

The Simple and Complex Measurements should be undertaken if the results of the Preliminary Assessment and the Questionnaire do not identify the problems, or if the remedial measures that have been taken do not alleviate them. The Questionnaire can also be used to check on the effectiveness of any remedial measures taken in Stage 1.

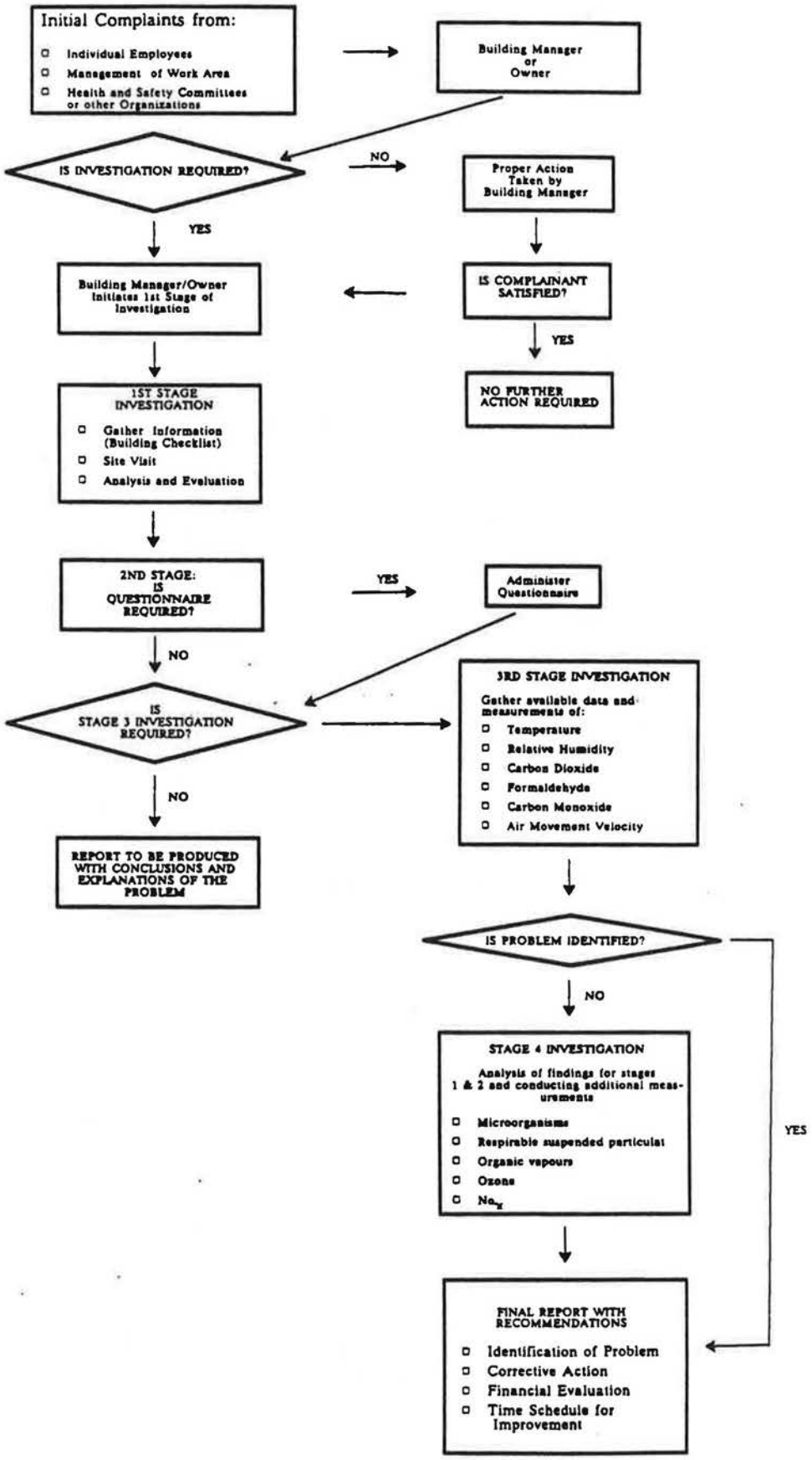
For each stage of the investigation, a separate decision should be made based on the information available. Stages 3 or 4 of the investigation should not be done without a clear indication that the problem cannot be identified at Stage 1 or after the administration of the Questionnaire.

5.2 Flow Diagram

The flow diagram (Fig. 5.1) 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.

Fig. 5.1

PROTOCOL FOR IAQ INVESTIGATION
FLOW DIAGRAM



5.3 Stage 1 - Preliminary Assessment

The preliminary assessment stage does not use instruments, but relies on an "inspection" and the "collection of information" on the 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, and
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. It is a questionnaire to be filled in about the building. Note that whenever possible, ventilation systems should be "visually" checked to ensure that they are performing in a satisfactory manner.

The Building Checklist is divided into five parts 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 Part 6, called 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.

5.4 Stage 2 - Questionnaire and Analysis

5.4.1 General

A comprehensive questionnaire has been developed as part of the protocol for IAQ investigation. The questionnaire is given in Appendix B and it is based on questionnaires that were developed by the Ministries of Labour and Health, and by J.D. McDonald of McGill University. Drafts of this questionnaire were reviewed by participating ministries' staff and, where applicable, their suggestions have been incorporated by the Committee.

The purpose of the questionnaire is to gather information on the problems that are experienced in the indoor environment. The questionnaire is designed to allow one to establish whether and to what extent IAQ problems exist, and what are the possible sources of contamination.

Questions have been defined which indicate symptoms that are typically associated with indoor air quality complaints. As well, the questionnaire probes the incidence of the more general complaints regarding exposure to physical conditions in the working environment, such as those relating to noise, lighting, humidity, temperature, air movement, etc. The format and language of the questionnaire is simple so as to allow individuals to complete it without assistance.

The questionnaire results can also be used in an analysis with the results of the contaminant measurements carried out in Stages 3 and 4. Among the contaminants which 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 assesses indicators of exposure and symptoms related to tobacco smoke.

5.4.2 Questionnaire Analysis

The analysis of the questionnaires for each IAQ investigation case is performed in three stages: i) analysis of each questionnaire ; ii) compilation of the results for all questionnaires; and iii) interpretation of the results. The responses (health symptoms) of highest frequency are determined. If responses are only directed to specifically one or a few health symptoms, it may be easy to infer a cause. If responses are directed at many, nonspecific health symptoms, then this may indicate the effects of "tight building syndrome" and the lack of fresh air.

The following discussion centres on the analysis of contaminants (e.g. physical conditions from the Questionnaire or chemicals measured in Stages in 3 and 4) against the frequency of health symptoms.

For each contaminant, questions relating to symptoms indicate the presence of complaints typically associated with the contaminant under review. The higher the symptom's score the greater the likelihood/severity of the symptoms associated with the contaminant in question. In each case, existence of a symptom is indicated by a value of "1" in the coded responses (see Appendix C). The maximum score is achieved with a score of "1" for each question.

To simplify matters, it is assumed that each indicator of symptoms or exposure will have equal weighting (ie. "1"). It is important to note that only symptoms which 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 are developed to assist in the analysis of the questionnaire (see Appendix D). As well, the "Lotus" software package is used in simplifying the analysis (see Appendix E). A summary table for individual questionnaires will provide information about each contaminant and severity of exposure (see Appendix F). Summary results of all questionnaires, for both symptoms and exposures, for different contaminants are compiled in a single table (see Appendix F).

To compare scores for all individuals in an investigation case, exposure and symptom scores can be plotted in the form of a frequency distribution chart (see Appendix F). 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 had an opportunity to reach a higher concentration. A frequency distribution for days of the week may assist in identifying the source of the problem (see Appendix F).

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 (Chi Square) to determine whether or not there is a significant relationship between indicators of exposure and symptom intensity (see Appendix F).

In the long term, the analysis of different IAQ investigation cases will provide information on some of the trends such as the relationship of IAQ problems to the sex of the respondents, type of office occupied, impact of other stress factors, etc.

5.5 Stage 3 - Field Measurements with Simple Instruments

The 3rd stage of the investigation involves simple instruments to take the following measurements:

- Temperature
- Relative Humidity
- Carbon Dioxide
- Formaldehyde
- Carbon Monoxide
- Air Movement.

This stage is needed only if Stage 1 does not identify the problem and Stage 2 indicates prevalence of certain symptoms.

In Stage 3, it is important that the above measurements are taken in the proper location and appropriate time of the year, week and day.
The tables in Appendix G 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 H provides ranges of acceptable and unacceptable values for various pollutants. The measurement results can be compared against these ranges. The measurements can also be used in an analysis with the health symptoms from the Questionnaire (see Section 5.4).

A list of simple pieces of equipment, which are often used for the monitoring of some basic pollutants, is given in Appendix I. The measurements should be easy, quick 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 four to measure other potential pollutants which require complex measurement techniques

5.6 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 would be necessary to use complex instruments to carry out further measurements of:

- Microorganisms
- Respirable Suspended Particulates
- Organic Vapour
- Ozone
- NOx
- Asbestos.

The complex measurement techniques are more time consuming and expensive to conduct than simple measurement techniques. They also require an experienced consultant or specialized organizations such as the Ministry of Labour or the Ministry of Health. These measurements are usually only used after Stage 1, 2 and 3 evaluations have failed to resolve the situation.

The measurements can also be used in an analysis with the health symptoms from the Questionnaire (see Section 5.4).

5.7 Interpretation of Field Measurements

Stage 3 and 4 measurements should be compared with Appendix H 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 in Chapter 4 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 locations give numbers in the 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 is 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.

CHAPTER 6

RECOMMENDATIONS

The Interministerial Committee on Indoor Air Quality recommends the following for consideration of the Deputy Minister's Committee on Occupational and Environmental Health.

6.1 Existing Buildings

(A) The "Protocol for Indoor Air Quality Investigation", including Questionnaire and Analysis, should be adopted to provide consistency throughout the province.

(B) A minimum of 15 cubic feet per minute per person of outdoor air should be provided so that carbon dioxide (an indicator of adequate fresh air) does not exceed 1,000 ppm.

For buildings without a complete mechanical ventilation system, full advantage should be taken of openable windows.

(C) Air velocity of an average of 30 (20 to 50) feet per minute should be provided at the work station.

(D) Winter temperatures should be between 19.5°C and 24.6°C, and summer temperatures between 22.6°C and 27.2°C.

(E) Pollutants (e.g. copy machines odours) source should be removed at their source.

(F) The levels of pollutants should be below the levels specified in Tables 4.8, 4.10 and 4.7.

(G) Viable organisms should not exceed 1,000 CFU/m^3 in indoor air.

6.2 New Buildings

For new buildings, the opportunity exists to design for adequate indoor air quality. Items 6.1 (B), (C), (D), (E), (F) and (G) are pertinent to this design. Reference is usually made to ASHRAE as good engineering practice. In addition to the above, the following items require careful attention in new building design:

(A) In areas where openable windows are not provided, mechanical ventilation throughout the occupied zone should be provided at a minimum of 15 cubic feet per minute per person and air velocity provided at the work station of approximately 30 feet per minute on average.

(B) Fresh air intakes should be located to avoid contamination, e.g. from street traffic.

(C) HVAC systems and materials should be designed to minimize the

opportunity for growth of micro-organisms, such as having self draining pans to avoid standing water.

(D) The building design should provide for readily accessible inspection and maintenance.

(E) The building design should provide for pollutant removal at the source

(F) Where practical, materials should be used that are low in pollutant emissions, e.g. drywall instead of particle board, and tile instead of carpeting.

(G) The above changes should be incorporated in the Building Code.

6.3 Second-Hand Smoke

These recommendations are based on the premise that second-hand smoke is a potential health hazard.

(A) All building areas normally occupied by the working population should be classified as non-smoking.

(B) Until such time as (A) above can be implemented, buildings affected should be provided with designated smoking areas. In designated smoking areas, at least 60 cfm of outdoor air per person should be provided and exhaust air from these areas should not be recirculated to other areas. However, in existing buildings, this may be economically impractical.

6.5 Future Recommendations

Evaluation and an appreciation of indoor air quality issues is just beginning. It is an important issue that requires continued attention. It is recommended that:

(A) The Deputy Minister's Committee on Occupational and Environmental Health should continue to review, assess, monitor and coordinate IAQ issues.

(B) The Deputy Minister's Committee should support the formation of a national body to review these issues and to carry out applied research towards resolving these issues.

(C) The Deputy Minister's Committee should support the development of maintenance guidelines for new and existing buildings by the HVAC industry.

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APPENDIX A: BUILDING CHECK LIST
(SOURCE: PWC. Indoor Air Quality Test Kit: User Manual, 1988)

PART 1: CARBON MONOXIDE - COMBUSTION BYPRODUCTS

Possible sources of carbon monoxide and combustion byproducts 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 number 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 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 usually left open or with the lids loose? Yes / No
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 on 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 economiser 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' nexts) lodged in the air intake? Yes / No
Are the intakes within 10 metres (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 slimeon 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). Otheriwse 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

Are there damp patches or mold on the wall or ceiling? Yes / No

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

Do the screens extend all the way down to the floor? 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, People, Inadequate ventilation and Pollutants. 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 eith 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 question (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 round 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 fibres (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 sent it to Building Performance for testing.

PART 6 Cont'd

Part 5 - COMPLAINT AREA OBSERVATION SHEET

To do the assessment, place this sheet to the right of the completed COMPLAINT AREA OBSERVATION SHEET, and overlapping 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 structural alterations or spray humidifier: dirt marks = particulates in the ventilation system
Yes = carbon dioxide

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

Yes = carbon dioxide

6) Pollutant Sources within 30 feet (10 metres)

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: QUESTIONNAIRE

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 teletypè 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: QUESTIONNAIRE CODIFICATION

QUESTIONNAIRE CODIFICATION

NOTE:
If there are two sets of number in the Code (i.e. 1.1 or 30.1) the first set of numbers (1 or 30) refer to the question number in the Questionnaire and the second set of numbers (1 in both examples) refers to the "answer" (row).

If there are three sets of numbers in the Code (i.e. 10.3.2) the first set (10) refers to the question number in the questionnaire; the second set of numbers (3) refers to the column number specified in the questionnaire; and last set of numbers (2) refers to "answer" (row).

	CODE	DATA	
(1)	1.1 1.2 1.3 1.4	0 or 1	Assign 1 if checked
(2)	2.1	Day Month Year	
(3)	3.1	hours (rounded)	
(4)	4.1 4.2 4.3 4.4	0 or 1	Assign 1 if checked Assign 1 if there is a response
(5)	N/A		
(6)	6.1 6.2	0 or 1	Assign 1 if checked
(7)	7.1 7.2	0 or 1	Assign 1 if checked
(8)	8.1 . . . 8.7	0 or 1	Assign 1 if checked
(9)	9.1 . . . 9.7	a number 0 to 8	

(10)	10.1.1	0 or 1	Assign 1 if circled
	.		
	.		
	.		
	10.1.7		
	10.2.1	a number (in months)	
	10.3.1(Mon-am)	0 or 1	
	10.3.2(Tue-am)		
	.		
	.		
	.		
	10.3.5(Fri-am)		
	10.4.1(Mon-pm)	0 or 1	
	10.4.2(Tue-pm)		
	.		
	.		
	.		
	10.4.5(Fri-pm)		
(11)	11.1.1	0 or 1	Assign 1 if circled
	11.1.2		
	11.1.3		
	11.2.1	a number (in months)	
	11.3.1(Mon-am)	0 or 1	
	11.3.2(Tue-am)		
	.		
	.		
	.		
	11.3.5(Fri-am)		
	11.4.1(Mon-pm)		
	11.4.2(Tue-pm)		
	.		
	.		
	.		
	11.4.5(Fri-pm)		
(12)	12.1.1	0 or 1	Assign 1 if circled
	.		
	.		
	.		
	12.1.8		
	12.2.1	a number (in months)	N/A

	12.3.1(Mon-am)	0 or 1	Assign 1 if circled
	.		
	.		
	.		
	12.3.5		
	12.4.1(Mon-pm)		
	.		
	.		
	.		
	12.4.5		
(13)	13.1.1	0 or 1	Assign 1 if circled
	.		
	.		
	.		
	13.1.5		
	13.2.1	a number (in months)	
	13.3.1	0 or 1	
	.		
	.		
	.		
	13.3.5		
	13.4.1		
	.		
	.		
	.		
	13.4.5		
(14)	14.1.1	0 or 1	Assign 1 if circled
	14.1.2		
	14.1.3		
	14.1.4		
	14.2.1	a number (in months)	
	14.3.1		
	.		
	.		
	.		
	14.3.5		
	14.4.1		
	.		
	.		
	.		
	14.5.5		

(15)	15.1.1 15.1.2 15.1.3 15.1.4	0 or 1	Assign 1 if circled
	15.2.1	a number (in months)	
	15.3.1 . . . 15.3.5	0 or 1	
	15.4.1 . . . 15.4.5		
(16)	16.1.1 . . . 16.1.5	0 or 1	Assign 1 if circled
	16.2.1	a number (in months)	
	16.3.1 . . . 16.3.5	0 or 1	
	16.4.1 . . . 16.4.5		

(17)	17.1.1 17.1.2 17.1.3 17.1.4 17.2.1 17.3.1 . . . 17.3.5 17.4.1 . . . 17.4.5	0 or 1	Assign 1 if circled
(18)	18.1 18.2	0 or 1	enter 1 if checked
(19)	19.1 19.2	0 or 1	enter 1 if checked
(20)	20.1.1 . . . 20.1.5 20.2.1(Mon-am) 20.2.2(Tue-am) . . . 20.2.5 20.3.1(Mon-pm) 20.3.2(Tue-pm) . . . 20.3.5	0 or 1	Assign 1 if circled

(21)	21.1.1 21.1.2 21.1.3 21.1.4 21.2.1 . . . 21.2.5 21.3.1 . . . 21.3.5	0 or 1	Assign 1 if circled
(22)	22.1.1 22.1.2 22.1.3 22.1.4 22.1.5 22.2.1 . . . 22.2.5 22.2.1 . . . 22.2.5	0 or 1	Assign 1 if circled
(23)	23.1.1 . . . 23.2.1 . . . 23.2.5 23.3.1 . . . 23.3.5	0 or 1	Assign 1 if circled

(24)	24.1.1 . . . 24.1.8 24.2.1 . . . 24.2.5	0 or 1	enter 1 if checked
(25)	N/A		
(26)	26.1 . . . 26.7	0 or 1	enter 1 if checked
(27)	27.1 27.2 27.3	0 or 1	enter 1 if checked
(28)	28.1 28.2	0 or 1	enter 1 if checked
(29)	29.1 29.2 29.3 29.4	0 or 1	enter 1 if checked
(30)	30.1 30.2	0 or 1	enter 1 if checked
(31)	31.1 31.2	0 or 1	enter 1 if checked
(32)	32.1 32.2	0 or 1	enter 1 if checked
(33)	33.1 33.2	0 or 1	enter 1 if checked
(34)	34.1 34.2	0 or 1	enter 1 if checked
(35)	35.0	Age in years	
(36)	36.1(male) 36.2(female)	0 or 1	enter 1 if checked

APPENDIX D: WORKSHEETS

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 - ~~CO2~~ 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 _____

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 - 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 =

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 E: LOTUS PROGRAM

25-Aug-88

QUESTIONNAIRE # 1

SURVEY QUESTIONNAIRE RESPONSE SHEET

ROW	Q.1	Q.2	Q.3	Q.4	Q.6	Q.7	Q.8	Q.9	Q.10.1	Q.10.2	Q.10.3	Q.10.4	Q.11.1	Q.11.2	Q.11.3	Q.11.4
1	1	880130	37	0			1	0	0	2	1	0	0	2	1	0
2	0			1			1	0	1		1	1	0		1	1
3	0			0			1	1	1		1	0	1		1	0
4	0			0			1	0	1		1	1			1	1
5							0	0			1	0			1	0
6							0	0	0							
7							0	0								
8																
9																
10																
11																

SURVEY QUESTIONNAIRE RESPONSE - 2

ROW	Q.12.1	Q.12.2	Q.12.3	Q.12.4	Q.13.1	Q.13.2	Q.13.3	Q.13.4	Q.14.1	Q.14.2	Q.14.3	Q.14.4	Q.15.1	Q.15.2	Q.15.3	Q.15.4
1	1	2	1	0	0	7	1	0	0	2	1	0				
2	1		1	1	0		1	1	0		1	1				
3	1		1	0	0		1	0	1		1	0				
4	0		1	1	0		1	1	0		1	1				
5	0		1	0	1		1	0	0		1	0				
6	0														1	
7	0															
8	0															
9																
10																

SURVEY QUESTIONNAIRE RESPONSE SHEET - 3

ROW	Q.16.1	Q.16.2	Q.16.3	Q.16.4	Q.17.1	Q.17.2	Q.17.3	Q.17.4	Q.18	Q.19	Q.20.1	Q.20.2	Q.20.3	Q.21.1	Q.21.2	Q.21.3
1	1	2	1	0			0		0	1	0	0	0	0	1	0
2	0		1	1			0				0	0	0	0	1	1
3	0		1	0			0				0	0	0	1	1	0
4	0		1	1			0				0	0	0	1	1	1
5	0		1	0			0				0	0	0		1	0
6																
7																
8																
9																
10																

SURVEY QUESTIONNAIRE RESPONSE SHEET - 4

ROW	Q.22.1	Q.22.2	Q.22.3	Q.23.1	Q.24.1	Q.24.2	Q.25	Q.26	Q.27	Q.28	Q.29	Q.30	Q.31	Q.32	Q.33	Q.34
1	1	1	0	0	0	0	0	0	0	1	1	0	1	0	1	0
2	0	1	1	0	0	0		0	0		0					
3	0	1	0	0	0	0		0	0		0					
4	0	1	1	0	0	0		0			0					
5	0	1	0		0	0		0								
6					0			0								
7					0			0								
8																
9																
10																

Q.35	Q.36
47	0

QUESTIONNAIRE ANALYSIS RESULTS

	VOC	FORMALD	OZONE	CO	RH	CO2	TEMP	AIRMOV	STRESS	PARTIC.	MICROBI	SMOKE
SYMPTOMS	6	1	1	N/A	3	N/A	N/A	1	4	N/A	1	6
MAX.	17	3	6		8			1	11		2	11
EXPOSURE	4	0	1	1	0	0	0	0	1	1	0	1
MAX.	13	3	2	8	3	2	3	1	7	8	2	1

APPENDIX F: FIGURES AND TABLES

APPENDIX 4B - 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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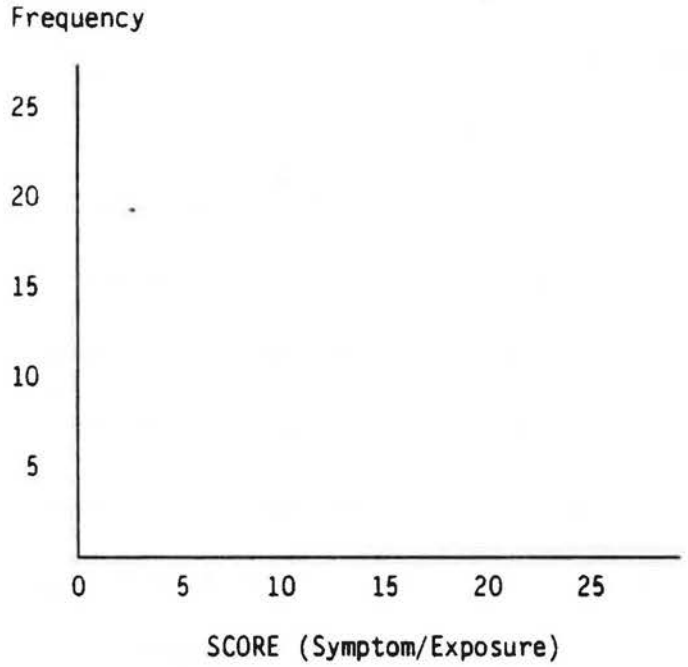
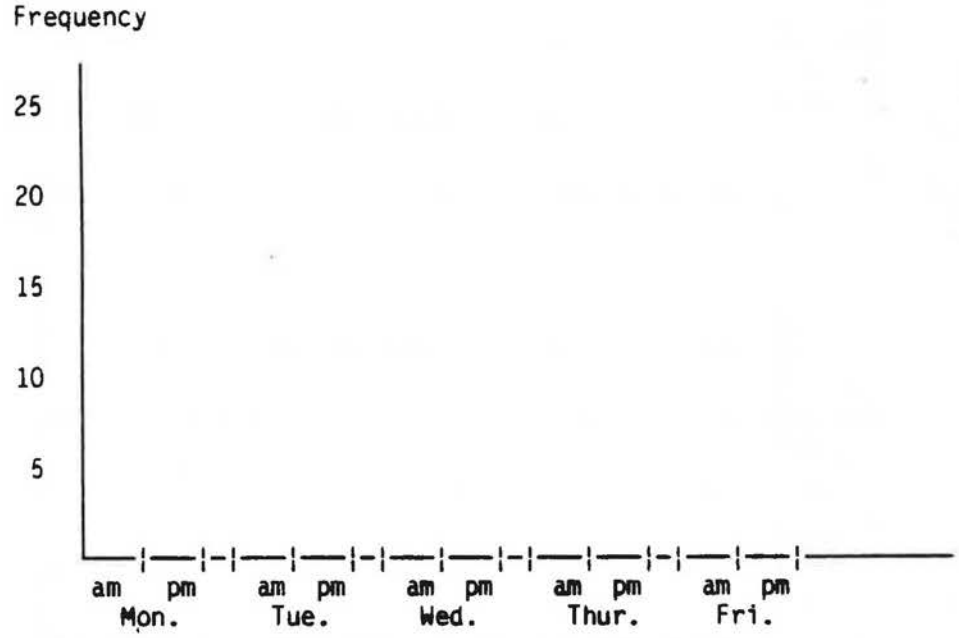
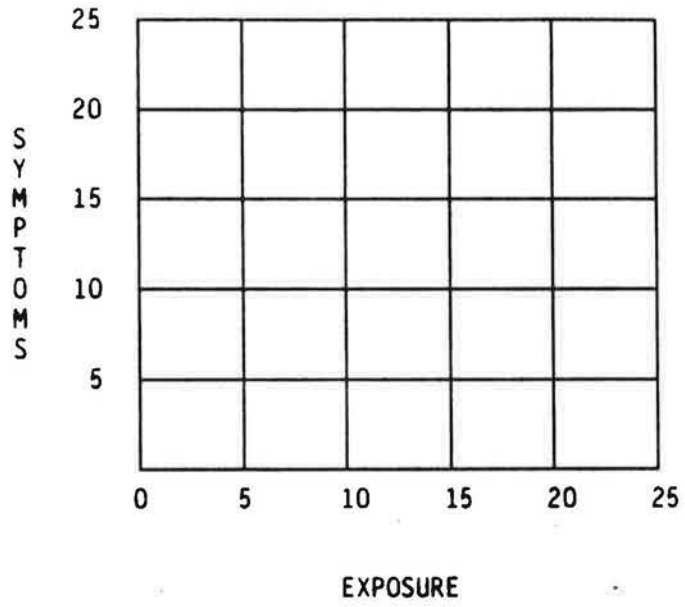
FREQUENCY DISTRIBUTION FOR EACH CONTAMINANT SYMPTOMS/EXPOSURE



FREQUENCY DISTRIBUTION FOR DAYS OF THE WEEK



CONTINGENCY TABLE



APPENDIX G: WHERE AND WHEN TO MEASURE
(SOURCE: PWC. Indoor Air Quality Test Kit: User Manual, 1988)

Table : 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 : 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 H

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
FORMALDEHYDE (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: 19.5-24.6C; summer tmperature: 22.6-27.2C; winter humidity: 25-85%; summer humidty: 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 I

INSTRUMENTATION FOR SIMPLE FIELD MEASUREMENTS

POLLUTANT/CAUSE	EQUIPMENT	UNITS OF MEASUREMENT
Carbon Dioxide	Fuji ZFP5	PPM
	Horiba APBA-210	PPM
Carbon Monoxide	ISD C0260	PPM
	Dynamation 104	PPM
	Gastec Colorimetric Tube	
Formaldehyde	ATL Chemical Kit	PPM
	Pro-Tek Passive Dosimeter	
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