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FINAL REPORT

OBJECTIVE DETERMINATION OF INDOOR AIR QUALITY USING PASSIVE AIR SAMPLERS AND BIOASSAYS

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SUMMARY

This report details the development and field testing of a passive sampler system to collect gaseous and particulate contaminants in indoor air and the evaluation of the collected materials for biological effects using a simple bioassay system. The passive sampler-bioassay system is a cost-effective objective method for determining indoor air quality.

The passive sampler for gaseous contaminants consists of activated molecular sieve 13X, while the passive sampler for particulates consists of a small vessel containing physiological phosphate buffer. The bioassay system used is the *Panagrellus redivivus* test, which can detect several types of adverse effects as well as detecting conditions conducive to microbial growth. The logic and experimental basis for the selection of the sampler and bioassay systems is detailed in the text.

Field studies of the sampler for gaseous contaminants was were carried out at 449 sites distributed among 19 buildings and 11 homes, while field studies of the particulate sampler were were carried out at 298 sites distributed among 9 of the buildings and 6 of the homes.

For most sites, no biological effects were detected by either the particle or absorbent sampler.

The absorbent sampler for gaseous contaminants detected adverse biological effects in 19.0% of the tested sites in buildings, and 14.2% of the tested sites in homes. These sites were normally areas of extensive cigarette smoking, areas containing solvents or gaseous by-products of some process localized within the tested area. The absorbent sampler detected growth stimulation in 11.5% of the tested sites in buildings, and in 14.2% of the tested sites in homes. These sites were normally in moist areas, or in areas containing textured materials (carpeting, ceiling tiles, office dividers) that had not been cleaned for a long period.

The particle samplers detected adverse biological effects at 24.9% of the tested sites in buildings and at 17.2% of the tested sites in homes. In buildings, these sites were often in areas near dry-process copiers, in areas near machine or welding shops, or in areas where large quantities of printed or typed documents were stored. In homes, these effects were usually in areas where indoor pesticides were applied, in insulation, or in cooking areas. Stimulatory particles were detected in 11.5% of the tested sites in buildings, and in 10.3% of the tested sites in

homes. These effects parallel the distribution of stimulatory effects detected by the absorbent sampler.

These results indicate that indoor air is extremely heterogeneous, even within a single structure with adequate ventilation.

In order to better understand the extent and type of health complaints resulting from poor indoor air quality, a questionnaire was developed and administered to 382 individuals in some of the buildings studied above. Sixty five percent of the respondents had air-quality related health complaints, and 46% of the respondents stated that the indoor air quality had a great or moderate effect on their job performance. The details of the questionnaire and health interviews are presented in Appendix I.

CHAPTER 1. INTRODUCTION

1.1. OVERVIEW

This project was initiated to develop a reliable, cost-effective method of objectively evaluating air quality and locating the primary sources of indoor air-related health complaints. The system that was developed consists of passive samplers used to collect gasses and particles from indoor air that can then be tested for toxic effects using a biological indicator. This report presents the logic, and scientific rationale for the development of the sampler/bioassay system used, and the results of preliminary field tests of the system.

Before discussing the logic underlying this sampler system, the overall problem of indoor air quality will be reviewed.

1.2 ONE PROBLEM OF INDOOR AIR: SICK BUILDING SYNDROME

1.2.1 The Indoor Air Environment

Canadians spend the vast majority of their time indoors; in schools, workplaces, and residences. While it has not been systematically investigated, there is growing evidence of increased discomfort due to the quality of indoor air. Anecdotal reports of increased absenteeism in new office buildings and schools, and complaints resulting from the use of some building materials, such as urea-formaldehyde foam insulation (UFFI), have raised questions about possible health consequences of indoor air pollutants. A generalized pattern of health complaints that may include respiratory discomfort, skin disorders, headaches, watering eyes, and nausea, have been linked to a response by some individuals to their workplace or residential air. These general conditions have been referred to as "tight-building syndrome" or "sick-building syndrome". These two terms have slightly different connotations. Tight building syndrome refers to health complaints that are the consequence of decreased air exchange with the outside, while sick-building syndrome refers to adverse effects resulting from an accumulation of materials within the building. The extent of these condition, or the long-term implications of tight-building syndrome and sick-building syndrome on health, comfort or productivity is not known.

In Canada, most buildings and residences have been built and designed to control the exchange of air between the interior of the structure and the outside environment. Because there is limited exchange between indoor and outdoor air, the overall composition of indoor and outdoor air may be quite different, with the indoor air containing a build-up of products of the activities within the structure and the establishment of localized concentrations of bacteria and molds within the indoor environment. Much of the strategy of energy-efficiency of the past decade has focused on further minimizing the exchange of air between indoor and outdoor environments, which has increased the chemical and microbiological differences between indoor and outdoor air.

There are many sources of contaminants in indoor air. Often specific activities within the building produce harmful by-products. Some building materials or furnishings may release potentially harmful vapors. Problems with indoor air may be due to trapping of outside contaminants drawn into a building by the ventilating system, or carried into the building on people entering the building. In this sense, the indoor air may function as a sink, increasing the levels of outside materials or providing environments in which microorganisms from the outside can flourish.

1.2.2 Specific Indoor Air Contaminants

It is generally accepted that there are a number of gasses that should be monitored and kept below specific levels in indoor air (Wadden and Scheff, 1983; Coon, 1984). Among these chemicals are:

1. ***Nitrogen oxides*** - recommended by NIOSH not to exceed 1 part per million in indoor air, although the EPA recommends levels not to exceed 0.5 ppm for a one year exposure in outdoor air.

2. ***Carbon dioxide*** - recommended in Japan not to exceed 1000 ppm in outdoor air, and by NIOSH not to exceed 3% for short periods or 1% for longer exposures indoors.

3. ***Carbon monoxide*** - recommended by EPA not to exceed 35 ppm for a 1 hour exposure or 9 ppm over an 8 hour exposure in outdoor air. NIOSH recommends levels not to exceed 3% for short exposures or 1% for longer exposures indoors.

4. ***Formaldehyde*** - recommended by NIOSH not to exceed ippm for short periods. HUD set the upper level at 0.4 ppm for mobile homes, and in Canada the guidlines are for 0.1 ppm.

5. ***Radon*** - recommended by EPA not to exceed 4 pCi/L and by NCRP as 8 pCi/l.

6. ***Viable Particles*** -levels in excess of 1000 colony forming units per cubic meter are considered as indicating serious contamination.

Less well defined in their accepted limits, but nevertheless generally considered to be chemicals that pose risk in indoor air

are ozone, oxides of sulfur, polycyclic aromatic hydrocarbons (PAHs), and higher aldehydes.

As well, indoor air contains particulates that could pose a risk to health and comfort. These include bacteria, fungi, and spores of these organisms, pollen, metals, dust containing bound contaminants, fiberglass and asbestos fibres.

To further compound the problem, there can be localized contamination with toxic chemicals resulting from specific human activities within a building, or originating from local outside air. It is also probable that there are other generally occurring toxic materials in air that have not yet been identified as toxic. It is quite likely that the list of toxic materials in indoor air will increase.

Given the diversity of causes for potential health problems stemming from indoor air, and our limited knowledge of toxic material in indoor air, it is not surprising that there is no widely accepted method for evaluating the actual quality of indoor air. Complaints about air quality often relate to comfort factors such as temperature, humidity or lighting. Complaints about "stuffiness" can indicate the accumulation of contaminating chemicals or microorganisms (especially molds), resulting from reduced air movement. Often, complaints stemming from indoor air quality are of a

very general subjective nature, providing little information that can be used in determination of the causes of the complaints. Therefore, the best methods for detecting air quality problems involves sampling of the air and objective laboratory evaluation of the collected samples.

1.3 MONITORING INDOOR AIR

Analysis of indoor air for specific contaminants is usually performed by active sampling of a volume of air, and using analytical instruments to determine the levels of the specific contaminants.

There are three major drawbacks to this approach:

1. Active sampling provides an indication of material in the air only during the short period that the sampling is taking place. Normally, the indoor activities that contribute to the generation or accumulation of contaminants occur in daily, weekly, or seasonal cycles. Active sampling, therefore, only provides a "snapshot" of conditions over a relatively very short time period.

2. This approach usually focuses only on a single contaminant. One widely used approach is to measure carbon dioxide, as the overall indicator of ventilation rates. However, if other contaminants are present, they would not be detected.
3. The more sensitive analytical methods for specific contaminants are expensive, and monitoring for a set of contaminants can be very costly. Methods for monitoring levels of several contaminants using a single analytical method (such as GC-MS) are even more expensive.

Another approach, widely used in workplace air evaluation in situations where known toxic material are known to accumulate, is the use of passive air monitors, placed at specific sites or issued to workers at specific sites. These monitors absorb the specific contaminants, and at periodic intervals are sent to laboratories for analysis. The absorbents are either extracted and the extract analyzed for levels of a specific chemical, or directly analyzed for a specific material, usually by direct colorometric methods. These relatively inexpensive passive monitors provide an indication of the total exposure to a specific contaminant. However, there are problems with such passive monitors. The absorbent material can become saturated with chemicals other

than the one for which the analysis is intended. One such common contaminant is water. Another problem is that the samplers will often absorb well at times when ambient concentrations of the target chemical is relatively high, but will desorb at low ambient concentrations.

Passive samplers give a representation of exposure to a specific material, while active sampling provides a measure of the specific concentration of a material in the air at a specific limited time period. Air quality and health standards can be based on either exposure or concentration of a specific material.

As pointed out previously, both active and passive sampling usually focuses on a single chemical compound, and such monitoring may not detect the specific material causing complaints in a specific indoor environment.

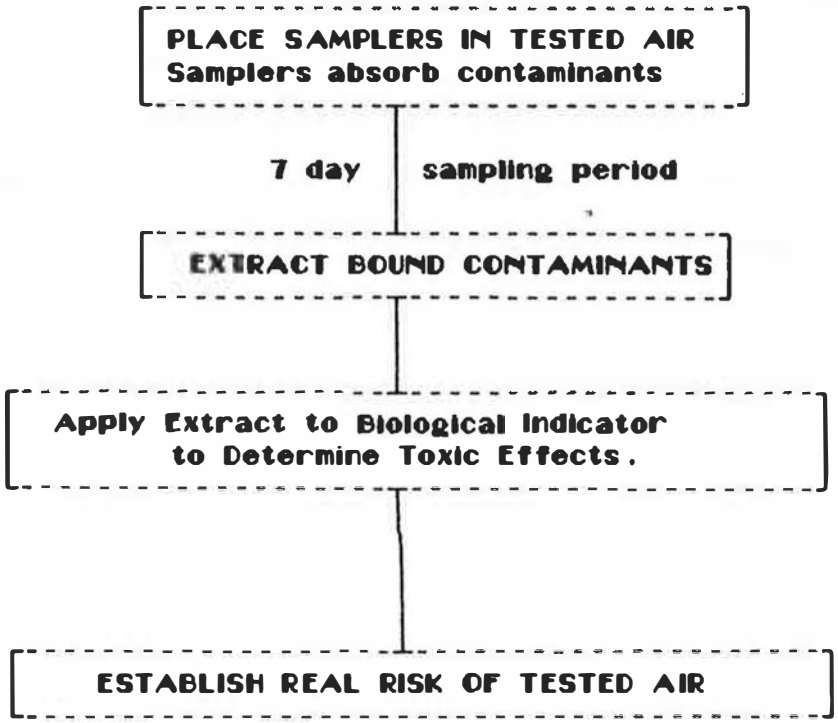
1.4.OBJECTIVES OF THIS PROJECT

Because there are no widely applicable, moderately inexpensive methods to evaluate air quality, and no broadly-based set of data on air quality of Canadian buildings. This study was carried out to develop a sampling protocol for

determining air quality, and to provide an indication of the extent of indoor air quality problems in Canada.

The project focused on the development of a passive sampler system capable of detecting the net toxic effect resulting from contaminants in indoor air. The logic of this system is shown in Figure 1-1. The project uses a simple biological test to determine net toxicity of absorbed air-borne contaminants.

FIGURE 1-1. THE LOGIC OF THE SYSTEM.



This approach to monitoring indoor air focuses on the net set of toxic effects, as determined by the test organism, resulting from the combined action of all the components of the indoor air, as contrasted to the conventional methods of merely quantifying the amounts of one or more specific contaminants.

CHAPTER 2

LOGIC AND DEVELOPMENT OF PROTOCOLS

2.1. CONFIGURATION OF SAMPLER

Central to the development of a protocol to couple passive monitoring of air to a bioassay to detect potential toxic effects of contaminants in the air is the determination of the general configuration of the sampler system. There are only two possible general configurations possible:

1. To physically locate the biological system in the indoor air environment to be tested, or
2. To use an absorbent to trap contaminants in the air *in situ*, and to elute these contaminants from the absorbent and then to perform the bioassay on the extract under laboratory conditions.

The first approach is similar to the traditional use of a captive bird by mineworkers as an indicator of carbon monoxide buildup. While logically sound, such a biological detection system is impractical for a number of reasons. Most currently used bioassays utilize organisms in aqueous medium; such organisms will respond to the fluctuations in light and heat within a building in a fashion that would influence the

toxic endpoints. To utilize a sufficient number of air-breathing, temperature regulating, test organisms in a residence or workplace would be most disruptive. It would be ridiculous, for example, to place a population of laboratory rats or mice in a typical residence or workplace. Furthermore, such tests would require long exposure periods to detect the subtle, non-lethal, effects that could be produced by indoor air contaminants.

The second approach has never been tried outside of this project, but is the configuration chosen. This approach relies on passive sampling to collect the contaminants in air, and a laboratory-based controlled bioassay as the analytical method to evaluate the net toxicity of these contaminants. In effect, the bioassay replaces analytical chemistry as the method used for the evaluation of air-quality.

The developmental phase of the project involved the selection of a bioassay system as well as the selection of the absorbent system. The bioassay must be relatively rapid and inexpensive, and be capable of detecting subtle long- and short- term toxic effects. The absorbent system must be capable of binding a wide range of contaminants, and the contaminants must be capable of being eluted from the absorbent by a solvent that is compatible with the bioassay system.

The following sections review the process by which the bioassay system, and the absorbent system were selected.

2.2. SELECTION OF A BIOASSAY

2.2.1 General Logic

One of the most widely used application of bioassays is in the process of licensing consumer-used chemical formulations, especially for agricultural or pharmaceutical use. This approach normally consists of a tiered set of bioassays, each used to establish a specific toxic endpoint of the material to be tested. The tiered structure, in which relatively inexpensive, rapid, simple biological indicators are used to establish general biological effects, while more expensive, longer term mammalian tests are used to establish a closer approximation to potential human health risks, has been the most widely accepted method for product licensing. The approach is cost-effective insofar as very toxic materials are screened out by the more inexpensive tests. However, the complete suite of tests for a single compound may cost several hundred thousand dollars, over a period of several years. Obviously a tiered set of tests on indoor air would be most impractical because of both cost and time constraints.

Another approach has been termed the "yardstick" approach by Samoiloff and Wells(1984). This approach involves the use of one of a limited number of standard simple tests to rank a large number of discrete samples, in order to focus upon those samples posing the greatest generalized toxic risk. This approach focuses on the comparative overall toxicity of one sample, relative to all other tested samples. The simple bioassay is selected on the basis of its ability to indicate very general toxic effects, ranging from lethality through to long-term effects, such as damage to the normal genetic functions of the test system.

This "yardstick" approach was selected as the method for the general evaluation of indoor air. It provides a means by which a series of air samples from within a single structure, or from several structures can be ranked in terms of their relative toxic effects on the indicator species.

2.2.2. Possible Bioassay Systems

There are numerous biological assays used in evaluating toxicity of environmental samples, chemicals or products. All of these tests determine some specific biological effect, referred to as the *biological end-point*, in a quantitative manner. The three most widely measured biological endpoints

are lethality, disruption of some physiological process, or mutagenesis. Most commonly, the end-point is measured as the percentage of a test population that shows the specific biological end-point, tested over a range of concentrations of the material being investigated.

Tests using lethality usually establish the ***concentration*** of the tested material at which it is calculated that 50% of the tested biological system dies after a specific exposure period (usually 96 hours). This concentration is referred to as the LC_{50} for that material. For tests to determine the LC_{50}, the slope of the relationship between the percentage of surviving members of the test population and the concentration of tested material is also calculated. A wide range of biological test systems, including bacteria, invertebrates, mammals, and mammalian (including human) cells grown *in vitro*, can been used to establish the LC_{50}. The value of the LC_{50}, and the slope of the "kill-curve" will vary from test system to test system.

Tests for inhibition of physiological processes usually are based on establishing the ***concentration*** at which 50% of the test population show the specific effect tested for. This value, extrapolated from dose-response studies, is termed the EC_{50}. There is a wide range of systems that are used for determining the EC_{50}, ranging from growth of bacteria or

2.2.3. The *Panagrellus redivivus* Bioassay

The bioassay using the nematode *Panagrellus redivivus* was developed primarily as a "yardstick" assay, to be used as a biological indicator of the overall toxic potential of complex mixtures, and to provide a rapid, cost-effective method to rank a series of tested materials (Samoiloff *et al*, 1980, Samoiloff *et al*, 1983). The bioassay gives a representation of broad biochemical or physiological effects of a general biological nature. As well as detecting toxic effects, the nematode bioassay can discriminate effects that promote the growth of microorganism (stimulatory effects), from direct chemical toxicity.

This bioassay exploits several unique features of the life-cycle of this free-living nematode. In nature the animals live in environments in which conditions for growth and maturation fluctuate. To accommodate these fluctuations, *Panagrellus* entrains its growth to environmental conditions. Under adverse conditions the animals arrest their growth, while under conditions conducive to growth the animals undergo rapid growth and maturation (Samoiloff. 1980).

Panagrellus takes in materials from its environment in two different fashions. Materials may enter directly via absorption through the body-wall. This transport is highly

invertebrates through to such subtle effects as the generation of tears in laboratory mammals. Such tests are much more applicable to indoor air quality determinations than are LC50 studies, since the biological endpoint of the EC50 test can be selected to more closely represent the types of effects produced in indoor environments. However, there is no biological test presently available that quantitatively and objectively measures the general pattern of symptoms associated with tight-building syndrome.

There are several methods for detecting mutagens, and this type of toxic effect should be monitored in indoor air. However, as the primary symptoms of tight-building syndrome reflect short-term physiological effects, none of these bioassays were considered for this project. During the course of this study, several air samples were tested for mutagenic effects by the "Ames test", using histidine auxotrophs of the bacterium *Salmonella typhimurium*.

The actual biological indicator system selected was the *Panagrellus redivivus* bioassay. As discussed in the following section, this test measures several biological endpoints

regulated and does not occur under adverse conditions. As well, the animals will ingest fluid and particles from their environment. Under adverse conditions, ingestion stops. The animal can ingest particles up to approximately 15μ in diameter.

Panagrellus undergoes live-birth, with newly born young animals (the L2 stage) approximately 300 micrometers in length. Under normal conditions, the animals will grow through three juvenile stages to an adult stage. Each stage has a characteristic size range, reflecting a limited number of tissue-specific developmental events. Between each stage is a period of molting during which the animal may continue growth ore arrest growth. The three larval stages, designated L2, L3 and L4, have size ranges of 300μ to 420μ, 420μ to 600μ, and 600μ to 800μ in length, respectively. Growth is completely dependent upon environmental conditions; under adverse conditions, animals will cease growing at either the L2-L3 molt or the L3-L4 molt. The adult attains a length of approximately 1500μ. Growth from L2 to adult takes 96 hours.

The growth of *Panagrellus* is achieved by an increase in cell size; the number of body cells remains effectively constant at 524. *Panagrellus* has multicellular digestive, excretory, nervous, and muscular systems, and any agent that

produces damage to any of these systems will prevent growth, and may result in death.

Studies on chemical and radiation mutagenesis (Samoiloff, 1980; Samoiloff *et al*, 1980; Burke and Samoiloff, 1980; Denich and Samoiloff, 1983), indicate that approximately 100 gene loci per animal are required for completion of the L2-L3 and L3-L4 molts, while approximately 2000 gene loci are required for completion of the L4-adult molt. Any agent producing either non-repairable damage to DNA or disruption of normal gene activity, by inhibition of either the regulation or processes of transcription or translation, will selectively inhibit the completion of this final molt. In earlier reports of this test (Samoiloff, 1980, Samoiloff *et al*, 1983), this effect was considered to reflect the presence of mutagens, and, indeed, mutagens do selectively inhibit the final molt (Samoiloff, 1980a, Samoiloff *et al*, 1980). However, agents acting on transcription or translation, but which are non-mutagenic also inhibit this final molt. To indicate these effects at the gene or gene action level, the term *phenotoxic* has been introduced (Samoiloff and Bogaert, 1984).

The *Panagrellus* bioassay is performed by setting up a known number (usually 10 replicates of 10 animals each in 0.5 mL of liquid) of L2 animals in a controlled limited nutrient medium in the presence of the tested material, and permitting

these animals to grow for a 96 hour exposure period. At the end of the test period, the number of animals surviving the exposure, and their size distribution, is determined. These values permit the determination of four specific biological effects:

A. *Lethality* - the test material causes a significant number of deaths, relative to a control population. Lethal effects indicate damage to an essential biochemical or physiological process. Such effects have not been found in indoor air samples.

B. *Growth Inhibition* - in which a significant number of the surviving animals in the test population fail to grow to the L3 or L4 stage, relative to a control population. This indicates damage or inhibition of a non-essential biochemical or physiological process.

C. *Phenotoxicity* - in which growth to the L3 and L4 stage is similar to that of the control population, but significant inhibition of the final molt occurs, relative to a control population. This effect indicates damage to the normal utilization of genetic information either by direct damage to DNA (mutation), or by preventing events of normal gene activity.

D. *Stimulation* - in which growth to the L3 and L4 stage occurs at a significantly greater rate in the tested population than in the control population. Stimulation of growth indicates that the tested material contains nutrients, and is suggestive of conditions that promote the growth of microorganisms.

The survival and growth of the test population is determined as a percentage of the control population. One other value, termed *fitness*, is obtained by calculating the degree of deviation of the growth and survival of the test population from that of the control population. This value expresses the overall well-being of the test population. The use of this value permits the ranking of a series of complex mixtures.

2.3. SELECTION OF AN ABSORBENT SYSTEM

2.3.1. Selection of Solvent System

The absorbent system was selected on its ability to bind a wide range of air-borne contaminants. The original sampler-bioassay concept was to utilize the sampler to trap contaminants, and then to remove these contaminants from the absorbent, using an appropriate solvent, for testing with the bioassay. One primary consideration in the selection of an absorbent system was the selection of an appropriate solvent system to remove absorbed contaminants from the air.

A series of organic solvents (acetone, dimethylsulphoxide, dioxane, ethanol, and methanol) were tested for toxicity in the *Panagrellus redivivus* bioassay in the concentration range (1%-5%) selected for bioassays of extracts from the absorbents. Only methanol and dimethylsulphoxide showed no toxic effects in this concentration range (Table 2-1).

However, dimethylsulphoxide showed variability between batches, and was relatively unstable, showing toxic effects several days after distillation (Table 2-2). Methanol was stable and non-toxic to the test animals in the desired concentration range. Therefore, methanol was selected as the solution for extraction of the sampler.

Table 2-1: Bioassays of Possible Extraction Solvents

The *Panagrellus bioassay* applied to a series of concentrations of possible extraction solvents.

Solvent	Concentration	Effect	Fitness
Acetone	0.3%	i	89
Acetone	0.8%	I	64
Acetone	1.7%	I	66
Acetone	3.3%	L	71
Acetone	8.3%	L	39
DMSO	0.8%	S	148
DMSO	1.7%	S	159
DMSO	3.3%	S	160
DMSO	5.0%	I	58
DMSO	8.3%	L	42
Dioxane	0.3%	I	69
Dioxane	0.8%	-	93
Dioxane	1.7%	L	11
Dioxane	3.3%	L	0
Dioxane	8.3%	L	0
Ethanol	0.8%	S	112
Ethanol	1.7%	S	117
Ethanol	3.3%	S	122
Methanol	0.8%	-	103
Methanol	1.7%	-	99
Methanol	3.3%	-	107
Methanol	8.3%	L	65

Key: DMSO = dimethylsulphoxide
L = Significant lethality of test animals
I = Significant inhibition of growth
i = Inhibition of maturation
S = Significant stimulation of growth
- = No significant Effect

Fitness is a weighted indicator of overall survival, growth and maturation of animals grown in the tested material, relative to controls.
Fitness less than 100 indicates inhibition.
Fitness greater than 100 indicates stimulation

Table 2-2: Bioassay of Dimethylsulphoxide.

The *Panagrellus* bioassay applied to dimethylsulphoxide.

Batch	Concentration	Effect	Fitness
#1	0.8%	S	148
#2 (distilled)	0.8%	S	112
#2 (1 week old)	0.8%	-	94
#1	1.7%	S	159
#2 (distilled)	1.7%	-	107
#2 (1 week old)	1.7%	-	100
#1	3.3%	S	160
#2 (distilled)	3.3%	I	72
#2 (1 week old)	3.3%	I	69
#1	5.0%	I	58
#2 (distilled)	5.0%	L	45
#2 (1 week old)	6.7%	I	54
#1	8.3%	L	42
#2 (distilled)	8.3%	L	22
#2 (1 week old)	8.3%	L	41

Key: 1 week old = 7 days after distillation.
storage at 4 degrees C.
L = Significant lethality of test animals
I = Significant inhibition of growth
i = Inhibition of maturation
S = Significant stimulation of growth
- = No significant Effect

Fitness is a weighted indicator of the overall survival, growth and maturation of animals grown in the tested material, relative to controls.
Fitness less than 100 indicates inhibition.
Fitness greater than 100 indicates stimulation.

2.3.2. Test of Methanol as a Solvent for Bioassays

To test the efficiency of methanol as a solvent system for toxic materials, a series of experiments were performed in which the toxicity of several materials dissolved in methanol was determined.

The toxicity of benzene dissolved in methanol was compared to benzene dissolved in acetone (Table 2-3). Using acetone as the solvent system, benzene toxicity could only be detected at the highest tested concentration tested (10^{-3} molar), while benzene toxicity using methanol as a solvent could be detected with the *P. redivivus* bioassay at concentrations down to 10^{-8} molar. The inability to detect benzene toxicity in acetone is due to the masking effects of the toxicity of acetone.

Another set of materials (acetaldehyde, formaldehyde, allyl alcohol, iso-amyl alcohol, and 1-octanol) was tested in 3% methanol. Allyl alcohol was lethal at 10^{-2} and 10^{-3} molar, but showed slight stimulation at 10^{-5} and 10^{-7} molar (Table 2-4). The 1-octanol was lethal at 10^{-2} molar, was inhibitory at 10^{-3} molar and 10^{-4} molar, and had no detected biological effect at lower concentrations (Table 2-4). Iso-amyl alcohol was toxic at all concentrations tested (Table 2-4). Formaldehyde caused significant inhibition of growth at 10^{-3}

and 10^{-4} molar concentrations, but had only slight inhibitory effects at lower concentrations (Table 2-5). Acetaldehyde showed toxicity in the concentration range 10^{-3} to 10^{-7} molar (Table 2-5).

Table 2-3: Toxicity of Benzene in Methanol or Acetone.

The *Panagrellus* bioassay applied to known concentrations of benzene in either acetone or methanol. Controls for benzene in acetone were run in 2% acetone, while controls for benzene in methanol were run in 2% methanol.

BENZENE CONCENTRATION	EFFECT	FITNESS
10^{-3} M (in 2% Methanol)	L	0
10^{-3} M (in 2% Acetone)	L	1
10^{-4} M (in 2% Methanol)	I	82
10^{-4} M (in 2% Acetone)	-	94
10^{-5} M (in 2% Methanol)	I	79
10^{-5} M (in 2% Acetone)	-	93
10^{-6} M (in 2% Methanol)	i	87
10^{-6} M (in 2% Acetone)	-	98
10^{-7} M (in 2% Methanol)	i	88
10^{-7} M (in 2% Acetone)	-	99
10^{-8} M (in 2% Methanol)	i	81
10^{-8} M (in 2% Acetone)	S	103

Key: L = Significant lethality of test animals
I = Significant inhibition of growth
i = Inhibition of maturation
S = Significant stimulation of growth.
- = No significant Effect

Fitness is a weighted indicator of the overall survival, growth and maturation of animals grown in the tested material, relative to controls.

Fitness less than 100 indicates inhibition.
Fitness greater than 100 indicates stimulation.

Table 2-4: Toxicity of Several Alcohols.

The *Panagrellus* bioassay applied to concentrations of octanol,iso-amyl alcohol, and allyl alcohol in 3% methanol. Controls were run in 3% methanol.

Tested Material	Effect	Fitness
10^{-2}M Allyl alcohol	L	0
10^{-3}M Allyl alcohol	L	0
10^{-4}M Allyl alcohol	-	103
10^{-5}M Allyl alcohol	S	105
10^{-6}M Allyl alcohol	-	100
10^{-7}M Allyl alcohol	S	103
10^{-2}M iso-amyl alcohol	L	15
10^{-3}M iso-amyl alcohol	L	39
10^{-4}M iso-amyl alcohol	I	41
10^{-6}M iso-amyl alcohol	I	49
10^{-7}M iso-amyl alcohol	I	61
10^{-2}M 1-Octanol	L	0
10^{-3}M 1-Octanol	I	88
10^{-4}M 1-Octanol	I	91
10^{-5}M 1-Octanol	-	99
10^{-6}M 1-Octanol	-	100
10^{-7}M 1-Octanol	-	97

Key: L = Significant lethality of test animals
I = Significant inhibition of growth
i = Inhibition of maturation
S = Significant stimulation of growth.
- = No Significant effect

Fitness is a weighted indicator of the overall survival, growth and maturation of animals grown in the tested material, relative to controls.
Fitness less than 100 indicates inhibition.
Fitness greater than 100 indicates stimulation.

Table 2-5: Bioassays of Formaldehyde and Acetaldehyde.

The *Panagrellus* bioassay applied to known concentrations of acetaldehyde and formaldehyde in 3% methanol. Controls were run in 3% methanol.

Tested Material	Effect	Fitness
10^{-3}M Acetaldehyde	I	56
10^{-4}M Acetaldehyde	I	62
10^{-5}M Acetaldehyde	I	65
10^{-6}M Acetaldehyde	I	85
10^{-7}M Acetaldehyde	i	93
10^{-8}M Acetaldehyde	-	95
10^{-3}M Formaldehyde	I	79
10^{-4}M Formaldehyde	I	83
10^{-5}M Formaldehyde	-	96
10^{-6}M Formaldehyde	i	93
10^{-7}M Formaldehyde	-	95
10^{-8}M Formaldehyde	-	97

Key: L = Significant lethality of test animals
I = Significant inhibition of growth
i = Inhibition of maturation
S = Significant stimulation of growth.
- = No Significant effect

Fitness is a weighted indicator of the overall survival, growth and maturation of animals grown in the tested material, relative to controls.
Fitness less than 100 indicates inhibition.
Fitness greater than 100 indicates stimulation.

2.3.4 Selection of Molecular Sieve as Absorbent

The selection of methanol as an extraction solvent for the absorbent sampler limits the number of potential absorbent materials that could be used for the samplers. The best absorbent seemed to be Molecular Sieve 13X, although preliminary tests were also carried out with poropak, XAD, and tenex.

The initial tests of absorbents were carried out in cubical glove boxes lined with polyethylene, containing a circulating fan and controlled input and output air flows. Formaldehyde gas was permitted to flow into the chamber at a rate sufficient to allow a steady-state concentration of 0.2 ppm of formaldehyde. Absorbent samplers containing 0.2g of molecular sieve 13X, poropak, XAD, and tenex were placed in the chambers for a 7 day sampling period. Other tests were performed using 0.4 and 0.8 grams of tenex, XAD, and poropak.

The results of these tests are shown in Table 2-6. After 7 days 3% methanol extracts of molecular sieve 13X showed a lethal effect on the bioassay, while similar extracts of XAD showed inhibition of maturation. Extracts of tenex and poropak showed no significant effects in the bioassay. As a result of these pilot studies, molecular sieve 13X was selected as the absorbent of choice for the sampler.

Table 2-6: Tests of Several Absorbents.

The results of the *Panagrellus redivivus* bioassay on 3% methanol extracts of molecular sieve 13X, tenex, poropak, and XAD exposed to controlled atmospheres of 0.2 ppm formaldehyde.

Tested Absorbent	Effect	Fitness
Molecular sieve 1 day	-	95
Molecular sieve 3 days	-	91
Molecular sieve 7 days	L	62
Poropak 0.2g (7 days)	-	94
Poropak 0.4g (7 days)	-	83
Poropak 0.8g (7 days)	-	94
Tenex 0.2g (7 days)	-	101
Tenex 0.4g (7 days)	S	104
Tenex 0.8g (7 days)	-	98
XAD 0.2g (7 Days)	i	95
XAD 0.4g (7 Days)	I	78
XAD 0.8g (7 Days)	i	93

Key: L = Significant lethality of test animals
I = Significant inhibition of growth
i = Inhibition of maturation
S = Significant stimulation of growth.
- = No Significant effect

Fitness is a weighted indicator of the overall survival, growth and maturation of animals grown in the tested material, relative to controls.
Fitness less than 100 indicates inhibition.
Fitness greater than 100 indicates stimulation.

2.3.5 Absorption-Desorption on Molecular Sieve 13X

One of the advantages of a passive monitor system is its ability to continuously absorb contaminants that may occur at different concentrations over the series of activity cycle that occur during the sampling period. However, this advantage would be lost if materials absorb when present in high concentrations in air, but desorb when the materials are present in lower concentrations in the ambient air than on the absorbent. Therefore, the absorption-desorption properties of the absorbent were investigated using formaldehyde gas as an indicator. Formaldehyde was selected as the indicator gas for these studies because it could be monitored at low concentrations in both the air and in the extract of the sampler. It is assumed that formaldehyde is a representative organic vapor for these studies.

The experiments, presented in Table 2-7, involved the exposure of a set of vials containing 2g molecular sieve 13X to a relatively high concentration (0.2ppm) of formaldehyde during an absorption period, then to lower the formaldehyde levels to 0.027 ppm to determine the desorption. During the course of the experiments samples of sieve were removed from the exposure chamber, the molecular sieve eluted with water, and the concentration of formaldehyde determined by colorometric means. The results shown in Table 2-7 demonstrate that, under the test conditions, the absorbents

become saturated with formaldehyde within 20 hours, but that no detectable desorption occurs, even after up to 20 hours at low formaldehyde concentration.

These studies further support the validity of the choice of molecular sieve 13X as the absorbent material for the passive air samplers.

Table 2-7: Absorption-Desorption of Formaldehyde.

Amounts of formaldehyde eluted with water from molecular sieve 13X exposed to high (2 ppm) and then low (0.027 ppm) levels of formaldehyde vapor.

Exposure Time	Formaldehyde Levels AIR(ppm)	ELUANT (ug/ml)
Absorption Period:		
0 hrs	0	0
2.5 hrs	0.20	1.86
2.5 hrs	0.20	1.36
23.0 hrs	0.22	3.54
23.0 hrs	0.22	4.45
26.0 hrs	0.238	2.90
26.0 hrs	0.238	4.18
Desorption Period:		
0 hrs	0.027	4.18
16.5 hrs	0.027	4.03
16.5 hrs	0.027	4.83
19.5 hrs	0.027	5.10
19.5 hrs	0.027	4.23

2.4. SAMPLING FOR PARTICULATES

During the field testing of the absorbent sampler, it became obvious that in some locations the health complaints stemming from indoor air were the consequence of particulates. Since the absorbent system was designed to detect biologically active vapors, it became necessary to design a passive sampler system to trap both viable and non-viable particulates for subsequent bioassay.

The passive sampler for particulates designed during this study consisted of a 7mL vial containing 4mL of M9 phosphate buffer (pH 7.2). The vial is opened during the sampling period, then resealed. A 10% dilution of the M9 buffer is tested for biological activity with the *Panagrellus redivivus* bioassay, while a second sample from the M9 buffer is plated on nutrient plates to determine microbiological contaminants.

2.5 CONCLUSIONS

This chapter has reviewed the logic and experiments leading to the development of the sampler system. On the basis of these points, the sampler/bioassay system consists of the following components:

1. *Panagrellus redivivus* is the biological indicator.
2. Activated molecular sieve 13X the absorbent used to trap gasses, and methanol is used to elute these trapped components from the molecular sieve.
3. M9 buffer as the fluid for the particle sampler.

The next chapter will report the methods used in preparing, using and analyzing the absorbent and particulate samplers, and will present a theoretical critique of the system..

CHAPTER 3

THE BIOQUEST SAMPLER SYSTEM

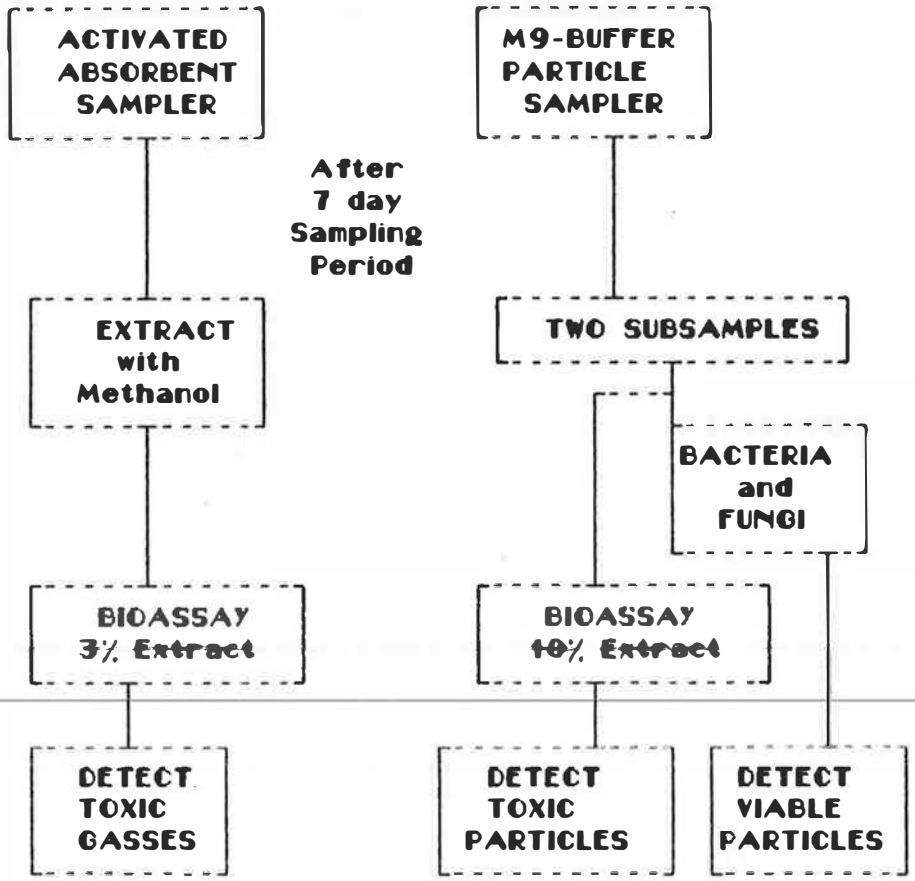
3.1. INTRODUCTION

The Bioquest Sampler system consists of a passive absorbent sampler, and a passive particle sampler. The absorbent sampler contains Molecular Sieve 13X, a fine absorbent powder, while the particle sampler contains M9-phosphate buffer, a liquid. A pair of samplers are placed in a tested indoor air environment, opened to ambient air, and left in place for a 7 day sampling period. During this period, the absorbent sampler binds contaminating gasses from the air, while the particle sampler traps viable and non-viable particulates from the air. At the end of the sampling period, the samplers are sealed, and returned to the laboratory where the trapped and absorbed materials are analyzed for toxic effects, using the *Panagrellus* bioassay.

The analyses of the absorbent samplers is carried out by extracting the samplers with methanol for 24 hours, and testing a 3% solution of this methanol extract for biological effects using the *Panagrellus* bioassay. At the same time, the particle sampler is analyzed for viable

particles by plating 0.5mL of the liquid onto nutrient agar plates. The particle sampler is analyzed for biological effects by testing a 10% solution of the liquid with the *Panagrellus* bioassay. These analyses provide data on biological effects of air-borne contaminants. The overall pattern of testing is shown in Figure 3-1.

Figure 3-1: Overview of Sampling and Testing.



3.2. THE ABSORBENT SAMPLER

Molecular Sieve 13X, 60/30 mesh, obtained from Supelco Inc., Bellefonte, Pennsylvania, is used as the absorbent material. The experimental justification for the use of this was presented in Chapter 2. Batches of approximately 50 grams of the absorbent are Soxhlet extracted with methanol, dried at 220°C., and stored in a dessicator until use. Just prior to use, the absorbent is activated by Soxhlet extraction with distilled water, followed by drying at 220°C.

The absorbent sampler consists of a 22.2mL Flint glass vial with a vinyl-lined screw cap (Fisher Scientific #03-338H). Activated molecular sieve (0.8g) is placed in the vial immediately prior to use, and the vial is sealed. A label with an identification number is attached to the outside of each vial.

In field studies, a pair of number-coded absorbent samplers are placed in at each tested site. One member of the pair is opened, acting as the test absorbent sampler, while the other sampler is kept sealed, acting as a reference blank. The samplers are left in place for a 7 day sampling period, then the test sampler is resealed, and the samplers returned to the Bioquest Laboratory for analyses.

Each sampler is extracted by addition of 20mL methanol. The samplers are extracted for a 24 hour period with periodic agitation. The molecular sieve is allowed to settle, and an 5mL aliquot of the methanol from each sampler is transferred to a number coded 7mL glass vial. A 3% solution of this methanol is tested for toxic effects by the bioassay.

A simple check has been devised to establish the efficiency of activation of absorbent, as reports (Judith Young, personal communication) indicated that some batches of molecular sieve 13X may be faulty. During the extraction of samplers, when each sampler is being opened for the addition of methanol, the individuals performing the extraction are instructed to listen for any sounds coming from a particular sampler as it is opened, and to record the number of any sampler which produces a hissing sound when first opened. Control samplers, not opened in the field, will produce such a hissing sound, as there has been some absorption by the absorbent of gasses within the closed control sampler, producing a lowered pressure within the sampler. Any batch in which the controls cannot be recognized by this hissing would be rejected. Such batches have not been detected.

3.3. THE PARTICLE SAMPLER

The particle sampler consists of liquid in a small vial. The liquid is M9-phosphate buffer, made up in 1000mL batches prior to use. The composition of M9 buffer is:/j

6g Na_2HPO_4

3g KH_2PO_4

5g NaCl

0.25g $MgSO_4$

1000 mL Distilled water

Freshly prepared buffer is sterilized by autoclaving.

Particle samplers are prepared by measuring 4mL of fresh M9-buffer in 7.4mL Flint glass vials (Fisher Scientific #03-338C) with vinyl-lined screw caps. Each particle sampler is autoclaved and then labelled with an identification number.

The particle samplers are opened and placed adjacent to the absorbent samplers for the 7 day sampling period. Normally the absorbent and particle samplers are connected by string to one another. Samplers can be suspended near the ceiling by draping the string over ceiling supports, or the string can be tacked to the ceiling or an area of wall, or the samplers can be placed on a desk, or attached to the legs of furniture.

At the end of the sampling period, the samplers are resealed and returned to the laboratory for analyses. An aliquot of the liquid is taken from the sampler, and used to prepare a 10% solution of the liquid for bioassay.

In some of the later field tests another aliquot of the liquid from the sampler is taken for microbiological testing. The total number and number of different types of colonies grown from 0.5mL samples of the M9-phosphate buffer were recorded on two different culture media; Standard Methods (Tryptone-Glucose-Yeast) agar plate for bacterial analysis and Sabouraud dextrose agar plate for fungal analysis. Both types of agar are purchased from BBL Microbiology Systems, Cockeysville, Maryland. These tests were performed to attempt to establish the *amount* of microbial contamination present, and did not involve direct identification of microbial species present.

The remaining fluid from the particle sampler is stored at 4°C. until the tests from the aliquots are completed. In some runs duplicate aliquots are prepared for bioassay as an internal check on reproducibility.

3.4. THE NEMATODE BIOASSAY

3.4.1 Preparation of Extracts

As samplers are returned from the field tests, a master key is prepared, recording the identification number of each absorbent and particle sampler used at each site. These samplers are grouped into "working groups" of 8-12 samplers each, containing the individual test samplers, and appropriate controls, reference blanks, and, in some cases, "spiked" reference samples. One individual, not involved with the actual testing, was given the responsibility of maintaining the master key,and preparing the "working groups" of samples. This individual then prepared the actual extracts extracts for testing, and the control, replicate, or spiked samples for that group, and posted a list of grouped sample numbers to be tested by one of 6 other individuals actually performing the bioassays. This ensured that all tests were performed on completely blind-labelled samples.

Methanol extracts from absorbent samplers, or 1 millilitre aliquots from the particle samplers were stored at 4°C. prior to testing. Normally, tests were performed within 3 days after the samplers were returned from field tests.

The methanol extract from the absorbent samplers or the liquid from the particle samplers are prepared for bioassay by dilution with M9-Y medium. This medium consists of M9-phosphate buffer, to which is added a small quantity of Baker's yeast as a nutrient source, and 1mL of ethanol containing 5mg of cholesterol, required for growth of the nematodes. The composition of the M9-Y medium is:

6g	Na_2HPO_4
3g	KH_2PO_4
5g	NaCl
0.25g	$MgSO_4$
5mg	dried Baker's yeast
1mL	ethanol containing 5mg/mL cholesterol
1000 mL	Distilled water

This medium is autoclaved after preparation.

For bioassays, a 0.3mL sample of the methanol extract from the absorbent sampler was added to 9.7mL of M9-Y medium for testing of this extract, while 1mL of the M9-buffer from a particle sampler was added to 9mL of M9-Y medium for testing of the particulates. Bioassays were performed in 0.5mL of the diluted test material in 2mL Autoanalyzer cups.

3.4.2 Setting Up Tests

The day before testing, gravid females of *P. redivivus* were transferred from stock plates to non-nutrient agar plates. The offspring of the females had no nutrients, so were arrested at the L2 stage. Approximately 10 females were transferred for each sample to be tested.

For bioassays, groups of 10 L2 animals are removed from the non-nutrient plate of gravid females and placed in each autoanalyzer cup containing test or control material. Ten replicates of 10 L2 animals each are set up for each test or control group, so 100 animals are tested for each sample. The autoanalyzer cups are capped, and allowed to incubate at 22_oC. for a 96 hour growth period. For each group of test and control animals, a group of 10 autoanalyzer cups containing only M9-Y medium is set up as a food control.

At the end of the growth period, the autoanalyzer cups are opened, and the number of surviving animals is determined. These survivors are removed from the autoanalyzer cups and placed in a small drop of medium on gelatin-coated glass microscope slides, heat killed, and stained with cotton-blue lactophenol. The image of the

animals is recorded on a Canon printing microfiche reader, and the size distribution of the animals in each group is measured on a Hewlitt-Packard 9835A computer, with graphics pad, using a program developed by Dr. Martin Samoiloff, University of Manitoba.

The data obtained for each group of animals, comprising a test of one sampler extract, control, blank, or spiked sample consist, therefore, of the following information:

1. The number of animals surviving from the initial population of 100 L2 animals.

2. The numbers of L2, L3, L4, and adult animals present at the end of the growth period.

These data are recorded and given to the individual who is responsible for maintaining the master key of the sites, and who enters the data, with site names, into an IBM PC computer for analysis and filing. A part of a typical data group is shown on the next page.

SAMPLE	%Survivors	L2	L3	L4	Adults
639	98	0	3	27	68
714	79	3	34	41	2
651	94	0	5	40	49

The sample # represents the blind labelled number assigned to each sampler, blank or control. In this case:
Sample 639 is a control.
Sample 714 is a spiked sample.
Sample 651 is from a site near a dry-process copier.

Data analysis is performed by a set of programs, developed in and compiled in BASIC. These programs perform both straight numeric and statistical analyses, as discussed in the following section.

3.4.3 Analysis of Bioassays

The values of survival, growth, maturation and fitness are all calculated relative to controls. *Survival* is the number of animals surviving in the test population relative to the number surviving in the control population. For the data shown above, survival of animals exposed to the extract of the sampler placed by the copier (Sampler 651) would be:

$$\%S = 100*(94/98) = 95.9$$

Growth is the percentage of the test population that reaches the L4 or adult stage, relative to this value in the control population. In the example above, growth of the population in the extract from the sampler placed near the copier (Sample 651) would be calculated as:

Growth = 100*(89/94)/(95/98) = 97.7

Maturation is the percentage of the L4 and adult animals in the test population that reach the adult stage, relative to this value in the control population. In the example above, the value for maturation in the extract taken from sample 651 would be:

Maturation = 100*(49/89)/(68/95) = 76.9

Fitness, a single value representing survival, growth and maturation is calculated as a weighted mean of the values of the survival relative to controls, the growth relative to the controls, and the maturation relative to controls. Fitness provides a single value by which the overall toxic effect of each member of a series of samples can be compared (Samoiloff *et al*, 1983), and is of primary use in the ranking of such a series of samples. Survival is given a weight equal to twice the growth, while growth is given a weight equal to twice the maturation. The justification for this weighting is that death is a more

severe toxic effect than is inhibition of growth, which is more severe than the inhibition of maturation. Fitness in the extract from the sample 651 is calculated as:

Fitness = ((4*95.9)+(2*97.7)+(76.9))/7 = 93.7

The statistical tests are performed by carrying out a chi-square contingency analysis of the values that comprise either survival, growth or maturation. The level of significance applied in these tests is $P<0.05$. A significant decrease in the number of survivors in the test population relative to that of the control population is designated as "*L*", for lethality. A significant decrease of the older individuals (L4s and adults) relative to the control population is designated as "*I*", while a significant decrease in adults is designated as "*i*". In some cases, the test population has a significantly greater number of older (L4 and adult animals). In this case, growth is shown as"*S*" to designate significant growth stimulation.

Several subjective criteria are also applied to each group of tests. If there is a significant difference between the food controls run with each group and the extracts from control samplers, or reference blanks, the group of samples is tested again. Periodically groups are prepared with "spiked" samples containing either 10^{-6} molar iso-amyl alcohol or 10^{-5} molar acetaldehyde. If the test

fails to detect significant inhibition of growth in these spiked samples, the tests are redone. In over 800 tests, no groups were required to be redone by the application of the above criteria.

This chapter has detailed the protocols used in setting up and analyzing the sampler/bioassay system. The next chapter will review the results of field testing of the samplers in workplaces and homes.

CHAPTER 4

FIELD STUDIES

4.1. OVERVIEW OF FIELD STUDIES

Field studies on the effectiveness of the passive sampler and bioassay system for evaluating air quality were carried out in 19 different workplaces and in 9 houses. The bulk of the workplaces were selected as representative of a broad range of diverse activities, while the homes selected were from the list maintained by the National Research Council UFFI group. Some of the workplaces were selected after consultation with Mr. Jim Switzer, Health Safety and Life Division, Manitoba Government Services. These workplaces were in buildings within which frequent worker complaints of air-quality related health complaints had been registered. For field tests in these latter locations, the actual areas within the building from which the health complaints originated was not revealed to Bioquest staff until the completion of testing and analyses.

Ideally, verification of the effectiveness of the sampler should proceed in a stepwise fashion as follows:

1. Tests are performed on a specific building, within which medically

documented air-quality related health problems occur.

2. On the basis of the tests, corrective measures are taken in areas identified by the test as having air-quality problems.
3. The area is retested by the sampler-bioassay system and medical examinations are made to detect changes in the health status of individuals in the building.
4. The sampler-bioassay and the medical examination should both demonstrate improvements in air quality.

However, for the great bulk of the buildings and homes tested, this was not possible. Usually, Bioquest staff approached either senior administrators within an office or shop, or approached the building engineers responsible for a particular building, to receive permission to place the samplers at their location. Access to medical records, internal health complaint records, or absentee records was not possible. The information provided by Bioquest on the air quality was, to our best information, rarely acted upon.

Medical information was generally not available from these locations. Therefore, in order to better understand the nature of air-quality related health problems, two

approaches were followed. Firstly, a questionnaire was developed for determining the extent and perception of air-quality related health complaints, and the perception of the causes for these complaints. Secondly, personal interviews were performed by medical students on a random cross-section of individuals within these buildings to develop a *general* set of medical histories of complaintants. However, to ensure confidentiality of the individuals questioned, guaurantees were made not to identify either individuals or specific work locations of these individuals. These studies, while not central to the development of the passive sampler-bioassay system for evaluating air quality, do suggest that health problems resulting from low indoor air quality are significant and frequent. The results of these studies are presented in Appendix I.

Despite the limitations discussed above, the field tests were carried out to determine the effectiveness of the passive sampler-bioassay system to detect areas of low air quality, and to establish the potential of the test system to indicate both causes and possible corrective actions. These results will be detailed in the following sections.

4.2. SUMMARY OF FIELD TESTS

For office buildings, reviewed in Table 4-1, a total of 706 sites in 19 buildings were tested with a total of 743 samplers. Absorbent samplers were tested at 390 sites in 19 buildings while the particle samplers were tested at a total of 269 sites in 9 buildings. The absorbent sampler found toxic effects at 74 sites (19% of those tested), and stimulatory effects at 45 sites (12% of those tested). The particle sampler detected toxic effects at 67 sites (25% of those tested), and stimulatory effects at 24 sites (9% of those tested). A total of 31% of all the sites tested by the absorbent sampler, and 34% of the sites tested with the particle sampler, showed contaminants in the air that could be detected by the bioassays.

For homes, a much smaller sample size was studied, as shown in Table 4-2. Eighty eight tests were done with the absorbent sampler at 57 sites in 10 homes, and the particle sampler at 29 sites in 5 homes. The absorbent sampler detected toxic effects at 7 sites (12% of the tested sites), and located stimulatory effects at another 7 sites (12% of the total number tested). The particle sampler trapped inhibitory materials at 5 sites (17% of the total tested), and stimulatory effects at 3 sites (10% of the total).

Two test absorbent samplers were placed at 37 of the tested sites to determine the reproducibility of the passive sampler-bioassay protocol. In each of these cases, the effects detected were identical for the two samplers, and the calculated fitness values were within 2 units of each other. Replicate particle samplers were placed at 26 sites, and the effects detected by the two replicates were identical, while fitness values never varied by more than 4 units between the two replicate samplers.

The details of the individual tested buildings and homes will be presented in the next sections.

TABLE 4-1. SUMMARY OF SAMPLER TESTS IN BUILDINGS

	ABSORBENT SAMPLER			PARTICLE SAMPLER		
SAMPLE	SITES	INHIB	STIM	SITES	INHIB	STIM
1200 PORTAGE	81	21	20	97	24	13
640 CORYDON	32	6	1	25	0	2
303 MAIN	38	5	4	28	5	1
COPIER SHOP	1	0	0	1	1	0
EATON PLACE	30	3	0	23	4	1
LAKEVIEW SQUARE	39	2	0	38	11	1
POST OFFICE	24	3	1	24	2	0
TECHNOLOGY CENTRE	17	4	0	17	9	6
ST. ANDREWS TOWER	16	6	6	16	12	0
ENVIRONMENTAL LAB	4	2	1	-	-	-
HOTEL	3	0	0	-	-	-
MANITOBA ARCHIVES	14	0	0	-	-	-
OVER PRINTSHOP	1	0	1	-	-	-
OLD GRAIN BUILDING	26	7	2	-	-	-
PARKADE	2	0	0	-	-	-
PRINT SHOP	5	1	3	-	-	-
RESTAURANT	7	2	0	-	-	-
ROYAL VISIT OFFICE	7	3	0	-	-	-
WOODSWORTH BLDG.	43	9	6	-	-	-
TOTALS	390	74	45	269	67	24
PERCENTAGES		19	12		25	9

TABLE 4-2. SUMMARY OF SAMPLER TESTS IN HOMES

	ABSORBENT SAMPLER			PARTICLE SAMPLER		
SAMPLE	SITES	INHIB	STIM	SITES	INHIB	STIM
HOME A	8	1	7	8	1	0
HOME B	3	0	0	3	0	0
HOME C	4	0	0	2	0	0
HOME D	10	3	3	8	0	3
UFFI HOMES	8	0	0	8	4	0
HOME E	8	3	0	-	-	-
HOME F	3	0	0	-	-	-
HOME G	5	0	0	-	-	-
HOME H	6	0	0	-	-	-
HOME I	4	0	0	-	-	-
TOTALS	59	7	7	29	5	3
PERCENTAGE		12	12		17	10

4.3 BUILDINGS

4.3.1 1200 Portage Avenue

This three-storey building is approximately 9 years old, and is occupied by provincial offices. Each floor has its own air circulating system. This building was suggested for field testing by Mr. Jim Switzer, Manitoba Government Services, Division of Life Safety and Health. Numerous complaints had been received, mainly from workers on the third floor. The analyses of samplers placed on the third floor of this building are shown in Table 4-3, for absorbent samplers, and Table 4-4 for the particle samplers.

Material trapped by the absorbent sampler placed at sites at the north-west end of this floor (rooms 301, the west end of 329 and the hall coffee room) were, for the most part, inhibitory, but the particle sampler failed to detect any toxicity in this area. This suggested that this area of the building is acting as either a sink or a source of gaseous contaminants in the air. However, there were no activities or processes unique to this area of the building that could account for the contamination of the air.

The general pattern of air circulation on the third floor is such that air from the roof heating and cooling intakes is passed by ducts to the northwest end of the third

floor, where the ducts branch into one main duct for the south side and one main duct for the north side. Return air moves from west to east through the headspace above the suspended ceiling. This movement of air very closely parallels the pattern of toxicity associated with the northwest areas of this floor.

In room 311 the absorbent samplers detected very significant stimulatory effects, while the particle samplers detected minor inhibitory effects. This area is below the humidification system, and water leakage on the ceiling had been noted on several occasions. Microbiological cultures from the particle samplers in this region revealed large numbers of bacteria and fungi, and a high species diversity.

Several areas around copiers and printers also showed some effects in both the absorbent and particle samplers. These are considered to be the consequence of increased levels of particles containing both carbon and metals, and therefore, producing both stimulatory and inhibitory effects.

During the course of the study of this building, the level of worker complaints became so serious that the provincial Minister responsible for this office ordered

staff moved to other working facilities until the study was completed.

Several actions were recommended as a consequence of this study. On the basis of the distribution of detected effects in the northwest corner, it was suggested that the ducting of the air circulating system be cleaned. It was found that dust removed from the ductwork was not toxic, but that high levels of carbonate-containing particles were present in the ductwork. These particle probably arose from precipitates of dissolved salts in the water used for humidification, which were drawn into the air circulating system. Such particles could cause skin disorders, as were reported for the northwest area.

The recommended corrective actions were taken, and the level of worker complaints fell below 10%. As a result, Bioquest was requested to examine the lower floors of this building. In these lower floors, as shown in Tables 4-5 and 4-6, the primary problem appears to be stimulatory material, probably originating from some microbial growth in the carpeting and materials used as surfacing on the space dividers.

This building was the most intensively studied, and these results show the ability of the sampler system to determine the areas with problem air, and to provide indications of the type of corrective actions required.

TABLE 4-3. 1200 PORTAGE THIRD FLOOR - ABSORBENT SAMPLER

SAMPLE	SURVIVAL	GROWTH	MATURE	FITNESS
301 Conference Rm	100 -	95 -	45 i	91 I
301 Conference Rm [low]	100 -	86 I	41 i	88 I
301 Dust #1	96 -	98 -	98 -	97 -
301 Dust #2	100 -	100 -	100 -	100 -
301 Main Center	98 -	111 -	41 I	94 i
301 Main Center [low]	97 -	100 -	3 i	84 i
301 Main Ov. Coff Tb	100 -	107 -	100 -	102 -
305 Computer Rm	99 -	100 -	100 -	99 -
305 Computer Rm [low]	100 -	97 -	100 -	99 -
305 Main	89 -	95 -	100 -	92 -
305 Main [low]	97 -	94 I	100 -	97 I
305 Over Table	100 -	102 -	100 -	101 -
305 JS	94 -	91 I	100 -	94 I
305 JS [low]	95 -	102 -	100 -	98 -
311 DS	100 -	110 S	100 -	103 S
311 DS [low]	100 -	110 S	100 -	103 S
313 By S. wall	100 -	99 -	30 i	90 I
313 Recept. desk [low]	100 -	101 -	40 i	92 I
313 Word proc. [low]	98 -	96 -	70 -	93 -
323 Main	95 -	100 -	100 -	97 -
323 Main [low]	97 -	105 -	100 -	100 -
323 over printer	98 -	101 -	100 -	99 -
323 printer [low]	100 -	90 I	100 -	97 I
325 Desk lev. VS	96 -	100 -	97 -	97 -
325 Education	94 -	102 -	92 -	96 -
325 SK	96 -	99 -	97 -	97 -
325 Storage Rm.	96 -	97 -	99 -	97 -
329 Below-behind copier	100 -	95 -	82 -	96 -
329 LB	94 -	91 I	100 -	94 I
329 Dust	100 -	101 -	100 -	100 -
329 E of Copier	100 -	99 -	41 i	91 i
329 Finance NW	100 -	85 I	32 i	86 I
329 Finance NW [low]	100 -	87 I	42 i	88 I
329 JG	97 -	99 -	95 -	97 -
329 JG [low]	100 -	101 -	100 -	100 -
329 MG	100 -	97 -	78 -	96 -
329 MG [low]	100 -	96 -	65 -	94 -
329 Storage	98 -	101 -	100 -	99 -
329 Word Processor	100 -	104 -	42 i	93 i
329 Word Processor [low]	98 -	94 -	47 i	90 i
CM	100 -	95 -	100 -	99 -
CM [low]	98 -	97 -	100 -	98 -
Desk Lev. VS	96 -	100 -	97 -	97 -

TABLE 4-3. 1200 Portage Absorbent (cont.)

SAMPLE	SURVIVAL	GROWTH	MATURE	FITNESS
Hall Coffee Rm	96	91	100	95
Hall Coffee Rm[low]	94	94	60	89
Hall by 313	91	91	100	92
Library	93	87	47	85
Library over Coffee	97	97	100	97
Library[low]	98	90	80	93
VS	100	99	100	100

TABLE 4-4. 1200 PORTAGE THIRD FLOOR - PARTICLE SAMPLER

SAMPLE	SURVIVAL	GROWTH	MATURE	FITNESS
301 Conference Rm	100 -	100 -	100 -	100 -
301 Conference Rm[low]	100 -	99 -	96 -	99 -
301 Main Center	99 -	100 -	100 -	99 -
301 Main Center[low]	100 -	99 -	99 -	100 -
301 Main Ov. Coff Tbl	100 -	101 -	100 -	100 -
305 Computer Rm	95 -	91 I	77 -	91 I
305 Computer Rm[low]	100 -	96 -	63 I	94 I
305 Main	98 -	98 -	87 -	96 -
305 Main[low]	96 -	101 -	71 -	94 -
305 Over Table	93 -	96 -	52 I	88 I
305 JS	94 -	97 -	88 -	94 -
305 JS [low]	95 -	100 -	88 -	95 -
311 DS	99 -	105 S	48 I	93 I
311 DS [low]	99 -	105 S	33 I	91 I
313 By S. wall	97 -	101 -	100 -	99 -
313 Recept. desk[low]	99 -	101 -	95 -	99 -
313 Word proc.[low]	100 -	101 -	100 -	100 -
323 Main	98 -	101 -	100 -	99 -
323 Main[low]	100 -	122 S	100 -	106 S
323 over printer	100 -	116 S	72 -	101 S
323 printer[low]	99 -	123 S	61 -	100 S
325 Desk lev. VS	99 -	99 -	78 -	96 -
325 Education	97 -	103 -	58 I	93 I
325 SK	98 -	100 -	73 -	95 -
325 Storage Rm.	97 -	105 S	100 -	100 S
329 Below-behind copier	95 -	99 -	96 -	96 -
329 LB	97 -	104 -	100 -	99 -
329 E of Copier	100 -	100 -	100 -	100 -
329 Finance NW	100 -	100 -	100 -	100 -
329 Finance NW[low]	100 -	101 -	99 -	100 -
329 JG	100 -	101 -	93 -	99 -
329 JG [low]	100 -	101 -	100 -	100 -
329 MG	100 -	101 -	100 -	100 -
329 MG [low]	100 -	101 -	100 -	100 -
329 LB	100 -	125 S	50 I	100 I
329 Storage	100 -	112 -	67 -	99 -
329 Word Processor	99 -	100 -	89 -	98 -
329 Word Processor[low]	100 -	101 -	100 -	100 -
CM	100 -	116 S	39 I	96 I
CM [low]	100 -	115 S	56 -	98 S
Hall Coffee Rm	95 -	95 -	98 -	95 -
Hall Coffee Rm[low]	94 -	95 -	92 -	94 -
Hall by 313	96 -	96 -	100 -	97 -
Library	99 -	95 -	58 I	92 I
Library over Coffee	100 -	99 -	71 -	96 -
Library[low]	93 -	95 -	60 I	89 I
VS	100 -	116 S	61 -	99 S

TABLE 4-5. 1200 PORTAGE FLOORS 1 AND 2 - ABSORBENT SAMPLER

SAMPLE	SURVIVAL	GROWTH	MATURE	FITNESS
115 Pension Fund	100 -	115 S	100 -	104 S
115 Pension Fund [low]	95 -	104 -	100 -	98 -
116 Coffee door	100 -	99 -	100 -	100 -
116 Desk [low]	100 -	98 -	83 -	97 -
116 Desk middle	100 -	113 S	100 -	104 S
116 Desk middle [low]	100 -	112 S	100 -	103 S
215 C	100 -	111 S	100 -	103 S
215 F	100 -	109 S	100 -	103 S
215 F [low]	100 -	103 -	88 -	99 -
215 Middle	100 -	102 -	100 -	101 -
215 Middle [low]	95 -	113 S	100 -	101 S
221 Curric Dev.	96 -	101 -	100 -	98 -
221 Curric Dev. [low]	100 -	100 -	100 -	100 -
227 Coffee Rm.	100 -	109 S	100 -	103 S
227 Coffee Rm. [low]	100 -	110 S	100 -	103 S
227 Copier	100 -	110 S	100 -	103 S
227 Copier [low]	100 -	107 -	100 -	102 -
227 Entrance	100 -	83 I	70 -	91 I
227 Middle	100 -	109 S	100 -	103 S
227 Middle [low]	100 -	106 -	100 -	102 -
227 Teacher Entran [low]	100 -	106 -	100 -	102 -
Boardroom	100 -	99 -	100 -	100 -
Boardroom [low]	100 -	99 -	100 -	100 -
CWA Desk Wrd Prc	100 -	99 -	100 -	100 -
CWA	100 -	100 -	100 -	100 -
Computer rm.	100 -	111 S	100 -	103 S
Computer rm. [low]	96 -	109 S	100 -	100 S
Copier Rm	100 -	92 -	71 -	94 -
Copier Rm [low]	100 -	102 -	88 -	99 -
Desk lev. near computer	100 -	110 S	100 -	103 S
G	97 -	97 -	100 -	97 -
G [low]	100 -	100 -	100 -	100 -
Kodak Copier rm.	97 -	108 S	100 -	101 S
Mc	100 -	106 S	100 -	102 S
Mc [low]	100 -	111 S	100 -	103 S
Pen. Fund Warehouse Cof.	94 -	94 -	95 -	94 -
Pen. Fund middle	100 -	115 S	100 -	104 S
Pen. Fund office	100 -	100 -	100 -	100 -
T off. Inner [low]	88 -	102 -	100 -	94 -
T off. Inner rm.	100 -	108 S	100 -	102 S

TABLE 4-6. 1200 PORTAGE FLOORS 1 AND 2 - PARTICLE SAMPLER

SAMPLE	SURVIVAL	GROWTH	MATURE	FITNESS
115 Pension Fund	95 -	101 -	64 I	92 I
115 Pension Fund[low]	99 -	100 -	58 I	93 I
116 Coffee door	97 -	96 I	48 I	90 I
116 Desk[low]	90 -	98 -	38 I	85 I
116 Desk middle	91 -	99 -	78 -	91 -
116 Desk middle[low]	98 -	97 -	64 I	93 I
215 C	100 -	100 -	100 -	100 -
215 F	100 -	100 -	100 -	100 -
215 F[low]	97 -	100 -	97 -	98 -
215 Middle	99 -	99 -	98 -	99 -
215 Middle[low]	99 -	99 -	99 -	99 -
221 Curric Dev.	100 -	121 S	100 -	106 S
221 Curric Dev.[low]	100 -	126 S	100 -	107 S
223 Desk	92 -	100 -	91 -	94 -
223 Desk[low]	100 -	100 -	100 -	100 -
223 Filing rm	98 -	99 -	93 -	98 -
223 Filing rm[low]	97 -	100 -	98 -	98 -
223 Off. Crnr SW	100 -	100 -	100 -	100 -
223 Off. Crnr SW[low]	100 -	100 -	100 -	100 -
225 Boardroom	93 -	100 -	94 -	95 -
225 Boardroom[low]	100 -	100 -	100 -	100 -
227 Coffee Rm.	100 -	122 S	100 -	106 S
227 Coffee Rm.[low]	100 -	129 S	100 -	108 S
227 Copier	98 -	100 -	100 -	99 -
227 Copier[low]	97 -	100 -	97 -	98 -
227 Entrance	100 -	126 S	100 -	107 S
227 Middle	99 -	100 -	97 -	99 -
227 Middle[low]	98 -	99 -	96 -	98 -
227 Stud. Records	100 -	100 -	100 -	100 -
227 Stud. Records[low]	100 -	100 -	100 -	100 -
227 Teacher Entran[low]	100 -	126 S	100 -	107 S
Boardroom	96 -	97 -	89 -	95 -
Boardroom[low]	92 -	98 -	64 I	90 I
CWA Desk Wrd Prc	91 -	94 I	59 I	87 I
CWA	95 -	89 I	64 I	89 I
Computer rm.	98 -	102 -	94 -	99 -
Computer rm.[low]	96 -	102 -	86 -	96 -
Copier Rm	100 -	100 -	98 -	100 -
Copier Rm[low]	98 -	100 -	72 I	95 I
Desk lev. near computer	98 -	100 -	77 -	96 -
G	98 -	96 I	39 I	89 I
Kodak Copier rm.	100 -	130 S	100 -	109 S
Mc	95 -	98 -	59 I	91 I
Mc [low]	98 -	98 -	74 -	95 -
Pen. Fund Warehouse C	100 -	103 -	44 I	93 I
Pen. Fund middle	96 -	103 -	62 I	93 I
Pen. Fund office	100 -	100 -	68 I	95 I
T off. Inner[low]	100 -	110 -	100 -	103 -
T off. inner rm.	100 -	106 -	100 -	102 -

4.3.2 640 Corydon Avenue

The building at 640 Corydon Avenue is an older office building housing electronic equipment. Inhibitory effects detected by the absorbent sampler were limited to a single office complex, the staff lounge, and areas around some machines, while stimulatory effects were found at a basement site (Table 4-7). The particle sampler did not detect any effects (Table 4-8).

The office area producing inhibitory effects was maintained under positive pressure, and the sites showing inhibitory effects were all near doors, suggesting that the observed effects were the result of materials being flushed into these areas by individuals entering and leaving these rooms. Reduction of the pressure, and increased ventilation were suggested to reduce this problem.

In the staff lounge, inhibitory effects were detected in the smoking areas.

The effects observed in the basement areas around some of the machines were primarily limited to older equipment, while newer versions of these machines did not produce effects.

TABLE 4-7. 640 CORYDON - ABSORBENT SAMPLER

SAMPLE	SURVIVAL	GROWTH	MATURE	FITNESS
3CL E	95 -	98 -	100 -	97 -
3CL Middle [low]	100 -	102 -	100 -	101 -
3CL W	93 -	98 -	98 -	95 -
Basement Batteries	99 -	103 -	100 -	100 -
Basement over generators	86 -	104 -	84 -	91 -
Basement Center Rm [low]	82 -	110 S	81 -	90 S
Basement East Power Rm	100 -	104 -	100 -	101 -
Basement New Rectifiers	100 -	107 -	98 -	102 -
Basement Recitifiers	96 -	87 I	100 -	94 I
Lounge	96 -	96 I	55 i	90 I
MIDAS Center	100 -	97 -	70 i	95 i
MIDAS Center [low]	96 -	101 -	98 -	98 -
MIDAS NE	87 -	100 -	100 -	93 -
MIDAS NE [low]	99 -	93 I	75 -	94 I
MIDAS NW	91 -	99 -	100 -	95 -
MIDAS NW [low]	91 -	103 -	100 -	96 -
MIDAS SE [low]	93 -	104 -	100 -	97 -
MIDAS SW	100 -	99 -	70 i	95 i
MIDAS SW [low]	100 -	96 I	72 i	95 I
TOPS SE [low]	99 -	101 -	100 -	100 -
Tops HOBIC	100 -	103 -	100 -	101 -
Tops HOBIC [low]	99 -	99 -	53 -	92 -
Tops NE	99 -	101 -	100 -	100 -
Tops NE [low]	97 -	98 -	100 -	98 -
Tops NW	100 -	102 -	100 -	101 -
Tops NW [low]	100 -	104 -	100 -	101 -
Tops SE	100 -	95 -	80 -	96 -
Tops SE EXT N	100 -	108 -	100 -	102 -
Tops SE Ext S	100 -	102 -	53 -	94 -
Tops SE Ext S [low]	100 -	99 -	100 -	100 -
Tops SW	100 -	102 -	100 -	101 -
lounge [low]	100 -	100 -	80 -	97 -

TABLE 4-8. 640 CORYDON - PARTICLE SAMPLER

SAMPLE	SURVIVAL	GROWTH	MATURE	FITNESS
3CL Middle [low]	99 -	100 -	96 -	99 -
3CL W	99 -	104 -	99 -	100 -
Lounge	99 -	99 -	87 -	97 -
MIDAS Center	100 -	101 -	100 -	100 -
MIDAS Center [low]	100 -	102 -	100 -	101 -
MIDAS NE	100 -	101 -	100 -	100 -
MIDAS NE [low]	100 -	101 -	100 -	100 -
MIDAS NW	99 -	101 -	100 -	100 -
MIDAS NW [low]	100 -	101 -	100 -	100 -
MIDAS SE [low]	100 -	102 -	100 -	101 -
MIDAS SW	100 -	106 -	99 -	102 -
MIDAS SW [low]	96 -	101 -	95 -	97 -
Tops HOBIC	100 -	101 -	100 -	100 -
Tops HOBIC [low]	98 -	100 -	94 -	98 -
Tops NE	95 -	101 -	96 -	97 -
Tops NE [low]	100 -	105 -	100 -	101 -
Tops NW	100 -	100 -	87 -	98 -
Tops NW [low]	100 -	105 -	100 -	101 -
Tops SE	99 -	101 -	85 -	98 -
Tops SE EXT N	100 -	100 -	100 -	100 -
Tops SE Ext S	99 -	100 -	90 -	98 -
Tops SE Ext S [low]	100 -	104 -	87 -	99 -
Tops SW	82 -	101 -	83 -	88 -
Tops SW [low]	100 -	103 -	94 -	100 -
lounge [low]	100 -	96 -	90 -	97 -

4.3.3 303 Main Street

The building at 303 Main Street is a 10 year old 16-storey multipurpose federal office building, containing offices on the lower floors, and agriculture laboratories on the top 4 floors. This building was examined using only the absorbent sampler in the summer of 1984, and then re-examined in the winter of 1985, using both the absorbent and particle samplers. The results are shown in Tables 4-9 and 4-10.

In the summer of 1984, inhibitory effects were found at low sites in the grain milling area, and in the mycology laboratory. Stimulatory effects were found in localized areas of one office that was examined, and in the protein analysis laboratory.

In the winter of 1985, the inhibition was detected by the absorbent sampler only in two chemical laboratories. The particle sampler found inhibitory materials in a welding area, a milling area, a pesticides lab, and in the mycology laboratory. Retesting of the mycology laboratory two weeks later found no inhibitory materials, which suggests that the inhibitory materials in this lab are transitory in nature. The hallway of the chemical lab area was found to contain stimulatory particles.

Studies in the winter of 1985 using absorbent samplers showed no effects on the office area. However, inhibitory material in the entry section of the office area was found with the particle sampler.

TABLE 4-9. 303 MAIN STREET - ABSORBENT SAMPLER

SAMPLE	SURVIVAL	GROWTH	MATURE	FITNESS
a. Summer 1984				
Lab - Baking	100 -	109 -	100 -	103 -
Lab - Milling high	100 -	101 -	76 -	97 -
Lab - Milling low	100 -	88 I	94 -	96 I
Lab - Mycology	98 -	105 -	62 i	95 i
Lab - Protein	100 -	109 S	100 -	103 S
Lab - Radiochem	100 -	102 -	76 -	97 -
Rm 500 Entry Area	98 -	110 S	100 -	102 S
Rm 500 No-smoking	93 -	113 S	100 -	100 S
Rm 500 Open Office	98 -	97 -	100 -	98 -
Rm 500 by carpet	100 -	119 S	100 -	105 S
b. Winter 1985				
1305 Malt Lab	100 -	100 -	100 -	100 -
1310 Oilseeds Rm	100 -	96 I	100 -	99 I
1310 Weight Rm	100 -	94 I	100 -	98 I
1318 Hallway	100 -	96 -	100 -	99 -
1318 Oilseeds Extraction	100 -	102 -	100 -	101 -
1324 Seeger Malting NE	100 -	91 I	100 -	97 I
1324 Seeger Malting Sink	100 -	96 -	100 -	99 -
1379 Shop Welding Area	100 -	101 -	92 -	99 -
1379 Shop main drill	100 -	101 -	83 -	98 -
1379 Shop milling	98 -	100 -	94 -	98 -
1379 Shop over lathe	100 -	101 -	98 -	100 -
1404 Administration	100 -	99 -	100 -	100 -
1404 Administration [low]	100 -	101 -	100 -	100 -
1540 Pesticide Center	100 -	101 -	100 -	100 -
1540 Pesticide by Hood	100 -	102 -	100 -	101 -
1540 Pesticide [low]	96 -	102 -	100 -	98 -
1603 Milling	100 -	98 -	100 -	99 -
1603 Milling [low]	100 -	99 -	100 -	100 -
1638 Mycology	97 -	100 -	94 -	97 -
1638 Mycology [low]	95 -	101 -	98 -	97 -
1679 Pilot Mill 2nd	100 -	103 -	100 -	101 -
1679 Pilot Mill 3rd	100 -	101 -	100 -	100 -
1679 Pilot Mill Main	100 -	104 -	100 -	101 -
1938 Mycology	98 -	100 -	98 -	99 -
Rm 500 Entry	94 -	97 -	83 -	93 -
Rm 500 Entry [low]	91 -	100 -	93 -	94 -
Rm 500 SW Corner	98 -	100 -	92 -	98 -
Rm 500 SW Corner [low]	90 -	99 -	89 -	92 -

TABLE 4-10. 303 MAIN STREET - PARTICLE SAMPLER

SAMPLE	SURVIVAL	GROWTH	MATURE	FITNESS
Winter 1985 only:				
1305 Malt Lab	85 -	101 -	87 -	90 -
1310 Oilseeds Rm	90 -	108 -	100 -	97 -
1310 Weight Rm	98 -	100 -	100 -	99 -
1318 Hallway	92 -	110 S	100 -	98 S
1318 Oilseeds Extraction	95 -	106 -	100 -	99 -
1324 Seeger Malting NE	98 -	102 -	100 -	99 -
1324 Seeger Malting Sink	89 -	99 -	100 -	93 -
1379 Shop Welding Area	99 -	93 I	79 -	94 I
1379 Shop main drill	100 -	100 -	100 -	100 -
1379 Shop milling	100 -	100 -	100 -	100 -
1379 Shop over lathe	100 -	100 -	100 -	100 -
1404 Administration	99 -	100 -	100 -	99 -
1404 Administration [low]	92 -	95 -	100 -	94 -
1540 Pesticide Center	93 -	102 -	100 -	97 -
1540 Pesticide by Hood	92 -	96 I	100 -	94 I
1540 Pesticide [low]	95 -	96 -	80 -	93 -
1603 Milling	96 -	101 -	81 -	95 -
1603 Milling [low]	91 -	95 I	50 I	86 I
1638 Mycology	93 -	94 I	83 -	92 I
1638 Mycology [low]	96 -	101 -	100 -	98 -
1679 Pilot Mill 2nd	96 -	98 -	88 -	95 -
1679 Pilot Mill 3rd	96 -	98 -	88 -	95 -
1679 Pilot Mill Main	95 -	103 -	100 -	98 -
1938 Mycology	100 -	100 -	100 -	100 -
Rm 500 Entry	88 -	101 -	75 -	90 -
Rm 500 Entry [low]	93 -	97 I	77 -	92 I
Rm 500 SW Corner	98 -	98 -	97 -	98 -
Rm 500 SW Corner [low]	96 -	98 -	100 -	97 -

4.3.4 Eaton Place

This building is an old warehouse, recently renovated, with a shopping mall on the lower floor and both federal and provincial offices on the upper floors. The office floors had high ceilings (18 ft), but poor ventilation, with carbon dioxide readings up to 1.6%. The results are shown in Tables 4-11 and 4-12.

Inhibition was detected by the absorbent samplers near input ducts in offices, and within a small self-contained computer room. The particle sampler found inhibitory materials in the computer room, by input ducts, and in smoking areas. Stimulatory particles were found in an area where papers have been stored for periods of time.

Many of the complaints in this building stemmed from comfort factors (low humidity, fluctuating temperature, poor lighting) rather than from contaminants in the air.

TABLE 4-11. EATON PLACE - ABSORBENT SAMPLER

SAMPLE	SURVIVAL	GROWTH	MATURE	FITNESS
5 Admin	100 -	101 -	100 -	100 -
5 Admin (by duct)	96 -	95 I	97 -	96 I
5 Geol Cutting Rm	94 -	102 -	95 -	96 -
5 Geol Lab (centre)	99 -	99 -	100 -	99 -
5 Geol Lab (centreB)	100 -	103 -	99 -	101 -
5 Geol Lab (m)	97 -	102 -	100 -	99 -
5 Geol Lab (middleB)	95 -	101 -	86 -	95 -
5 Geol Wash	79 -	92 -	86 -	84 -
6 Mail Rm	100 -	100 -	95 -	99 -
6 Main	97 -	100 -	95 -	98 -
6 Main [low]	100 -	100 -	100 -	100 -
6 Office #1	100 -	100 -	100 -	100 -
6 Office #2	100 -	99 -	100 -	100 -
6 Office #3	100 -	100 -	99 -	100 -
715 Computer Rm	93 -	101 -	96 -	96 -
715 Computer Rm [low]	87 -	95 I	94 -	90 I
715 Interior Rm	100 -	96 I	100 -	99 I
715 Interior Rm [low]	100 -	99 -	100 -	100 -
9 Accounting	100 -	100 -	100 -	100 -
9 Accounting Storage	100 -	101 -	95 -	100 -
9 Accounting [low]	100 -	100 -	100 -	100 -
9 Admin Over Desk	99 -	99 -	100 -	99 -
9 Admin by Vent	99 -	98 -	100 -	99 -
9 Admin [low]	100 -	99 -	97 -	99 -
9 Computer Rm	95 -	100 -	94 -	96 -
9 Computer Storage	98 -	100 -	100 -	99 -
9 Mail Machine Rm	100 -	100 -	94 -	99 -
9 Mail Rm	93 -	100 -	100 -	96 -
9 Mail Store Rm	98 -	99 -	91 -	97 -

TABLE 4-12. EATON PLACE - PARTICLE SAMPLER

SAMPLE	SURVIVAL	GROWTH	MATURE	FITNESS
5 Geol Cutting Rm	100 -	98 -	100 -	99 -
5 Geol Wash	100 -	102 -	100 -	101 -
6 Mail Rm	100 -	101 -	100 -	100 -
6 Main	100 -	103 -	100 -	101 -
6 Main [low]	100 -	97 -	100 -	99 -
6 Office #1	100 -	96 -	100 -	99 -
6 Office #2	100 -	97 -	100 -	99 -
6 Office #3	100 -	95 -	100 -	99 -
715 Computer Rm	93 -	93 I	58 I	88 I
715 Computer Rm [low]	98 -	102 -	78 -	96 -
715 Interior Rm	97 -	99 -	78 -	95 -
715 Interior Rm [low]	100 -	93 -	100 -	98 -
9 Accounting	85 -	68 I	49 I	75 I
9 Accounting Storage	100 -	102 S	100 -	101 S
9 Accounting [low]	99 -	102 -	92 -	99 -
9 Admin Over Desk	98 -	88 I	65 I	90 I
9 Admin by Vent	96 -	93 I	64 I	91 I
9 Admin [low]	100 -	101 -	100 -	100 -
9 Computer Rm	100 -	103 -	100 -	101 -
9 Computer Storage	98 -	105 -	91 -	99 -
9 Mail Machine Rm	100 -	98 -	100 -	99 -
9 Mail Rm	100 -	101 -	100 -	100 -
9 Mail Store Rm	100 -	105 -	100 -	101 -

4.3.5 Lakeview Square

Lakeview Square is a 5-year old office building used by both federal and provincial agencies for offices. Only the basement and bottom 3 floors were tested.

Numerous complaints were made by individuals working in one small basement office. The absorbent sampler detected inhibition only at a low site in the entry area of this office (Table 4-13), while the particle sampler found inhibition at every site except for a low site in the conference room (Table 4-14). After these results were reported, the carpets were steam cleaned, old ceiling tiles were replaced, and the walls disinfected. Re-testing of the area showed no effects. Prior to cleaning, one very large fungal growth was noted on one ceiling tile in the entry area.

Inhibitory effects were found by the absorbent sampler at a low site at one end of the coffee room in another small basement office. Inhibitory and stimulatory particles were also found in the coffee room. The absorbent sampler found no effects in the tested areas in the upper floors, but the particle sampler detected inhibition in two small offices on the upper floors. One of these offices had been vacant for 3 months, the other was rarely used.

TABLE 4-13. LAKEVIEW SQUARE - ABSORBENT SAMPLER

SAMPLE	SURVIVAL	GROWTH	MATURE	FITNESS
Before (B) and After (A):				
B Boiler Room (B)	100 -	98 -	80 -	97 -
B Boiler Room (A)	89 -	100 -	93 -	93 -
B Conference (B)	100 -	99 -	89 -	98 -
B Conference (A)	100 -	99 -	100 -	100 -
B Conference[low](B)	98 -	94 -	97 -	97 -
B Conference[low](A)	100 -	100 -	100 -	100 -
B Copier Room (B)	100 -	100 -	92 -	99 -
B Copier Room (A)	86 -	98 -	80 -	89 -
B Entry (B)	100 -	98 -	100 -	99 -
B Entry (A)	100 -	99 -	100 -	100 -
B Entry[low] (B)	96 -	95 I	100 -	96 I
B Entry[low] (A)	100 -	100 -	100 -	100 -
B EC Coffee Rm E[low]	100 -	102 -	100 -	101 -
B EC Coffee Rm N	100 -	102 -	100 -	101 -
B EC Coffee Rm N[low]	99 -	94 I	98 -	97 I
B EC Coffee Rm W	96 -	100 -	95 -	97 -
B EC Coffee Rm W[low]	98 -	100 -	100 -	99 -
B EC End Office	97 -	100 -	100 -	98 -
B EC End Office[low]	88 -	100 -	88 -	91 -
B EC Entry Wall	100 -	99 -	100 -	100 -
B EC Entry[low]	100 -	101 -	100 -	100 -
Rm 214 Back Office	100 -	100 -	100 -	100 -
Rm 214 Back Office[low]	100 -	101 -	97 -	100 -
Rm 214 Entry	100 -	101 -	100 -	100 -
Rm 214 Entry - Printer	95 -	101 -	93 -	96 -
Rm 214 Entry[low]	95 -	100 -	97 -	97 -
Rm 214 Over Copier	92 -	100 -	93 -	94 -
Rm 305 Back Office	93 -	98 -	96 -	95 -
Rm 305 Back Office[low]	88 -	100 -	86 -	91 -
Rm 305 Entry	90 -	97 -	86 -	91 -
Rm 305 Entry[low]	93 -	99 -	94 -	95 -
Rm 305 Over Printer	95 -	98 -	96 -	96 -
Rm 305 Storage Rm	89 -	99 -	82 -	91 -
Rm 307 Empty Office	93 -	100 -	90 -	95 -
Rm 307 Empty Office[low]	100 -	100 -	100 -	100 -
Rm 307 Entry	100 -	100 -	100 -	100 -
Rm 307 Entry[low]	100 -	100 -	100 -	100 -
Rm 307 Over Copier	100 -	100 -	100 -	100 -

TABLE 4-14. LAKEVIEW SQUARE - PARTICLE SAMPLER

SAMPLE	SURVIVAL	GROWTH	MATURE	FITNESS
Before (B) and After (A):				
B Boiler Room (B)	94 -	83 I	82 -	89 I
B Boiler Room (A)	82 -	101 -	100 -	90 -
B Conference (B)	97 -	93 I	100 -	96 I
B Conference (A)	100 -	99 -	100 -	100 -
B Conference [low] (B)	91 -	102 -	77 -	92 -
B Conference [low] (A)	95 -	98 -	100 -	97 -
B Copier Room (B)	97 -	93 I	100 -	96 I
B Copier Room (A)	88 -	99 -	100 -	93 -
B Entry (B)	98 -	88 I	41 I	87 I
B Entry (A)	100 -	97 -	100 -	99 -
B Entry [low] (B)	98 -	97 -	55 I	92 I
B Entry [low] (A)	100 -	97 -	100 -	99 -
Hallway	93 -	88 I	77 -	89 I
B EC Coffee Rm E [low]	95 -	93 -	100 -	95 -
B EC Coffee Rm N	94 -	94 -	100 -	95 -
B EC Coffee Rm N [low]	90 -	109 S	100 -	97 S
B EC Coffee Rm W	100 -	91 I	100 -	97 I
B EC Coffee Rm W [low]	96 -	88 I	100 -	94 I
B EC End Office	100 -	103 -	100 -	101 -
B EC End Office [low]	99 -	91 -	100 -	97 -
B EC Entry Wall	91 -	84 I	70 -	86 I
B EC Entry [low]	97 -	102 -	100 -	99 -
Rm 214 Back Office	100 -	97 I	100 -	99 I
Rm 214 Back Office [low]	97 -	99 -	99 -	98 -
Rm 214 Entry - Printer	100 -	100 -	100 -	100 -
Rm 214 Entry [low]	100 -	101 -	100 -	100 -
Rm 214 Over Copier	97 -	99 -	100 -	98 -
Rm 305 Back Office	92 -	98 -	100 -	95 -
Rm 305 Back Office [low]	89 -	106 -	88 -	94 -
Rm 305 Entry	91 -	107 -	100 -	97 -
Rm 305 Entry [low]	88 -	95 -	100 -	92 -
Rm 305 Over Printer	90 -	97 -	77 -	90 -
Rm 305 Storage Rm	95 -	101 -	77 -	94 -
Rm 307 Empty Office	84 -	86 I	100 -	87 I
Rm 307 Empty Office [low]	91 -	103 -	100 -	96 -
Rm 307 Entry	99 -	100 -	100 -	99 -
Rm 307 Entry [low]	100 -	100 -	100 -	100 -
Rm 307 Over Copier	96 -	100 -	100 -	98 -

4.3.6 Post Office Building

This is a 20-year old multipurpose office building. The ground floor has large drive through areas for delivery trucks. No Post Office areas were tested; studies were limited to federal offices on the 6th to 9th floors. The results are given in Tables 4-15 and 4-16.

Stimulatory effects with the absorbent samplers were detected at a low site in one non-renovated office. Inhibitory gasses were detected by the absorbent sampler in a smoking area, and over an area where graphics work was being performed. Particle samplers revealed stimulatory effects by a set of liquid copiers, in an isolated computer room, and at one low point in the non-renovated office, and found inhibitory effects at another site in the non-renovated office.

At one site, by a hole in a ceiling panels in a little used corner of an eighth floor mail room, the particle sampler detected lethal effects, while the absorbent sampler detected no effect. This site was retested, with lethal effects detected in the particle sampler, and no effect detected in the absorbent. No worker complaints were reported on this floor, although few

individuals spent more than several minutes in this part of the room.

The major complaints from workers in this building involved extremes of the temperature, although some individuals also complained of a general stuffiness.

TABLE 4-15. POST OFFICE BUILDING - ABSORBENT SAMPLER

SAMPLE	SURVIVAL	GROWTH	MATURE	FITNESS
11 Main Air Filters	100 -	101 -	100 -	100 -
Rm 1000 EnvCan	97 -	103 -	100 -	99 -
Rm 1000 EnvCan.[low]	100 -	102 -	100 -	101 -
Rm 1000 Reception	100 -	101 -	92 -	99 -
Rm 600 Stats Copiers	97 -	101 -	100 -	99 -
Rm 600 Stats Main[low]	100 -	109 -	100 -	103 -
Rm 600 Stats SE	100 -	111 -	100 -	103 -
Rm 700 DSS Coffee Rm	100 -	98 -	76 -	96 -
Rm 700 DSS Entry	100 -	100 -	74 -	96 -
Rm 700 DSS Entry[low]	100 -	106 S	100 -	102 S
Rm 700 DSS South[low]	100 -	91 I	93 -	96 I
Rm 800 CEIC Mail	100 -	102 -	100 -	101 -
Rm 800 CEIC Mail[low]	100 -	99 -	100 -	100 -
Rm 800 CEIC Main	100 -	103 -	85 -	99 -
Rm 800 CEIC Main[low]	100 -	102 -	86 -	99 -
Rm 800 Computer Main	100 -	97 -	100 -	99 -
Rm 800 Computer Printer	100 -	102 -	64 i	95 i
Rm 800 Computer Tape Rm	98 -	97 -	62 -	93 -
Rm 900 Computer (Fax)	99 -	99 -	91 -	98 -
Rm 900 Computer (mid)	100 -	99 -	100 -	100 -
Rm 900 Weather	100 -	95 I	83 -	96 I
Rm 900 Weather [low]	100 -	97 -	97 -	99 -
Rm 905 Sci. Ser.	99 -	101 -	89 -	98 -
Rm 905 Sci. Ser. (I)	98 -	99 -	99 -	98 -

TABLE 4-16. POST OFFICE BUILDING - PARTICLE SAMPLER

SAMPLE	SURVIVAL	GROWTH	MATURE	FITNESS
11 Main Air Filters	100 -	104 -	100 -	101 -
Rm 1000 Env. Can.	97 -	105 -	100 -	100 -
Rm 1000 Env. Can.[low]	100 -	105 -	100 -	101 -
Rm 1000 Reception	99 -	104 -	100 -	101 -
Rm 600 Stats Copiers	93 -	108 S	100 -	98 S
Rm 600 Stats Main[low]	88 -	106 S	87 -	87 S
Rm 600 Stats SE	98 -	108 S	100 -	101 S
Rm 700 DSS Coffee Rm	93 -	105 -	100 -	97 -
Rm 700 DSS Entry	98 -	106 S	100 -	101 S
Rm 700 DSS Entry[low]	92 -	108 S	100 -	98 S
Rm 700 DSS South[low]	100 -	108 S	100 -	102 S
Rm 800 CEIC Mail	57 L	0 I	0 I	33 L
Rm 800 CEIC Mail[low]	100 -	101 -	100 -	100 -
Rm 800 CEIC Main	100 -	95 -	100 -	99 -
Rm 800 CEIC Main[low]	98 -	100 -	87 -	97 -
Rm 800 Computer Main	100 -	105 -	100 -	101 -
Rm 800 Computer Printer	93 -	108 S	95 -	98 S
Rm 800 Computer Tape Rm	92 -	108 S	100 -	98 S
Rm 900 Computer (Fax)	100 -	101 -	100 -	100 -
Rm 900 Computer (mid)	99 -	104 -	100 -	101 -
Rm 900 Weather	99 -	101 -	100 -	100 -
Rm 900 Weather [low]	97 -	105 -	100 -	100 -
Rm 905 Sci. Ser.	100 -	98 -	100 -	99 -
Rm 905 Sci. Ser.[low]	93 -	99 -	89 -	94 -

4.3.7 Industrial Technology Centre

This building is a newer single-level building, containing an office, library, chemical lab and machine shop, all of which are interconnected. It houses both provincial and federal employees. Results are shown in Tables 4-17 and 4-18.

Inhibitory vapors were found in the main office area, by the carpets in the reception area, and near a machine-controller. The particle sampler showed inhibitory effects in the reception area, the main office area, and in a small outer office.

There were numerous complaints on air quality from workers in this building.

TABLE 4-17. INDUSTRIAL TECHNOLOGY CENTRE - ABSORBENT SAMPLER

SAMPLE	SURVIVAL	GROWTH	MATURE	FITNESS
Chem lab	91 -	101 -	100 -	95 -
Instrument Lab	100 -	101 -	100 -	100 -
Library Stacks	100 -	100 -	95 -	99 -
Library by Copier	96 -	97 -	80 -	94 -
Library[low]	100 -	101 -	100 -	100 -
Machine Controller	100 -	94 I	93 -	97 I
Machine Shop Center	100 -	107 -	100 -	102 -
Machine Shop North	100 -	102 -	100 -	101 -
Main	100 -	97 -	100 -	99 -
Main West	100 -	92 I	100 -	98 I
Main desk top	100 -	102 -	100 -	101 -
Main[low]	100 -	94 I	100 -	98 I
Metalurgy Lab	90 -	97 -	85 -	91 -
Reception	100 -	97 -	100 -	99 -
Reception over copier	100 -	114 -	100 -	104 -
Reception[low]	100 -	94 I	100 -	98 I
Small Outer Office	100 -	104 -	100 -	101 -

TABLE 4-18. INDUSTRIAL TECHNOLOGY CENTRE - PARTICLE SAMPLER

SAMPLE	SURVIVAL	GROWTH	MATURE	FITNESS
Chem lab	96	99	96	97
Instrument Lab	98	101	96	99
Library Stacks	100	101	100	100
Library by Copier	100	99	100	100
Library[low]	100	100	100	100
Machine Controller	100	99	100	100
Machine Shop Center	100	100	100	100
Machine Shop North	97	100	89	97
Main	100	93	86	96
Main West	100	99	88	98
Main desk top	100	96	81	96
Main[low]	92	91	82	90
Metalurgy Lab	100	101	100	100
Reception	90	87	63	85
Reception over copier	90	100	69	90
Reception[low]	90	92	84	90
Small Outer Office	98	95	81	95

4.3.8 St. Andrews Tower

This location is a control tower at a small airport, a five-story tall, narrow, self-contained structure. The working areas are relatively small, and several workers are heavy smokers.

As is shown in Table 4-19, inhibitory gasses were detected in four of the office areas, a basement power room, the operations area, and the coffee room. Particle samplers (Table 4-20) found inhibitory material in the coffee room, 4th floor office, and the operations area. The fourth floor office is occupied by two heavy smokers.

Although this building had a very high proportion of sites with adverse effects detected by the samplers, the four people, all smokers, in the building during the times of testing had few complaints about air quality.

TABLE 4-19. ST. ANDREWS TOWER - ABSORBENT SAMPLER

SAMPLE	SURVIVAL	GROWTH	MATURE	FITNESS
1st Telecommunications	100 -	102 -	67 I	96 I
2nd Conference Rm	100 -	113 S	100 -	104 S
2nd Conference Rm closet	100 -	101 -	100 -	100 -
2nd Conference Rm [low]	100 -	112 S	100 -	103 S
3rd Office 304 copier	100 -	118 S	100 -	105 S
3rd Office 304 [low]	100 -	112 S	100 -	103 S
3rd Office 305	91 -	105 -	100 -	96 -
3rd Office 305 [low]	100 -	117 S	100 -	105 S
4th Coffee Rm	100 -	95 I	88 -	97 I
4th Coffee Rm [low]	100 -	100 -	100 -	100 -
4th Office 408	100 -	100 -	87 -	98 -
4th Office 408 [low]	100 -	95 I	100 -	99 I
5th Operations	94 -	99 -	33 i	87 i
5th Operations (ledg	95 -	78 I	24 i	80 I
5th Operations [low]	98 -	82 I	27 i	83 I
B Power Rm	92 -	106 S	100 -	97 S

TABLE 4-20. ST. ANDREWS TOWER - PARTICLE SAMPLER

SAMPLE	SURVIVAL	GROWTH	MATURE	FITNESS
1st Telecommunications	97 -	101 -	100 -	99 -
2nd Conference Rm	97 -	84 I	45 I	86 I
2nd Conference Rm closet	94 -	75 I	55 I	83 I
2nd Conference Rm[low]	97 -	82 I	23 I	82 I
3rd Office 304 copier	98 -	95 -	45 I	90 I
3rd Office 304[low]	95 -	90 I	82 -	92 I
3rd Office 305	94 -	89 I	27 I	83 I
3rd Office 305[low]	98 -	84 I	36 I	85 I
4th Coffee Rm	96 -	90 I	100 -	95 I
4th Coffee Rm[low]	95 -	94 I	100 -	95 I
4th Office 408	96 -	96 -	100 -	97 -
4th Office 408[low]	95 -	90 I	100 -	94 I
5th Operations	97 -	96 -	100 -	97 -
5th Operations (ledge)	93 -	99 -	100 -	96 -
5th Operations[low]	100 -	94 I	100 -	98 I
B Power Rm	97 -	79 I	32 I	83 I

4.3.9 Old Grain Building

The Old Grain Building is an older building, which has been recently renovated. The activities of this building are very much like those of the newer grain building at 303 Main Street. This building was only tested by the absorbent sampler (Table 4-21).

Stimulatory effects were found in a laboratory involved with pesticide residues on agricultural products, and in a germination laboratory. Inhibition was detected in a room in which infected crops were stored, in office areas with many smokers, and in two locations in a print-shop area.

TABLE 4-21. OLD GRAIN BUILDING - ABSORBENT SAMPLER

SAMPLE	SURVIVAL	GROWTH	MATURE	FITNESS
03 H&W Lab	99 -	102 -	100 -	100 -
03 H&W Office	88 -	76 I	100 -	86 I
03 H&W Office [low]	100 -	106 -	100 -	102 -
03 H&W Pesti.	99 -	129 S	81 -	105 S
04 Animal Pathology	86 -	102 -	78 -	89 -
04 DSS Print	100 -	86 -	33 i	86 i
04 DSS Print [low]	100 -	92 -	22 i	87 i
04 PWC Copier	99 -	119 -	100 -	105 -
04 PWC Main Area	94 -	75 I	100 -	89 I
04 PWC [low]	96 -	85 -	11 i	81 i
05 EC Data Rm	100 -	113 -	99 -	104 -
05 EC Main	98 -	102 -	97 -	99 -
05 EC Storage	100 -	93 -	100 -	98 -
05 EC Storage [low]	100 -	98 -	99 -	99 -
07 Corn Smut Lab	80 -	104 S	52 I	83 i
07 Germin. Lab	100 -	112 -	98 -	103 -
07 Germin. Lab [low]	100 -	105 S	100 -	101 S
07 Office	94 -	104 -	84 -	95 -
07 Office (by carpet)	100 -	100 -	100 -	100 -
07 Plant Health	95 -	109 -	100 -	100 -
07 Seed Storage Rm	100 -	99 -	100 -	100 -
07 Storage	94 -	101 -	100 -	97 -
07 Storage [low]	98 -	92 -	98 -	96 -
B-21 Corner [low]	100 -	100 -	100 -	100 -
B-21 Mid-area	93 -	98 -	90 -	94 -
B-21 Pesticide Area	98 -	98 I	96 -	98 I

4.3.10 The Woodsworth Building

This is a large office building, used by provincial and city offices. This building was only tested by absorbent sampler, as reported in Table 4-22.

Stimulatory effects were found in one area of the 7th floor, and by the entry area of a 15th floor suite. The effects on the 7th floor were centered about an area in which a portable humidifier had been used, and which subsequently numerous complaints of respiratory difficulties, watering eyes, and sinus discomfort had been reported. These health complaints and the stimulatory effects detected by the passive sampler-bioassay system were removed after steaming of the carpet and the replacement of ceiling tiles in this area.

Inhibitory effects were found in storage areas on the 4th, 13th and 15th floors where old records were being held, suggesting that old papers could be a source of contaminating materials. Inhibitory effects were also found in tests of the water of the main air intake humidification system.

TABLE 4-22. WOODSWORTH BUILDING - ABSORBENT SAMPLER

SAMPLE	SURVIVAL	GROWTH	MATURE	FITNESS
04 Entry	98 -	100 -	100 -	99 -
04 Hall	96 -	86 I	66 i	89 I
04 Small Office	98 -	105 -	100 -	100 -
04 Storage	99 -	99 -	97 -	99 -
04 Storage [low]	99 -	98 -	56 i	93 i
07 Above Ceiling	100 -	108 S	100 -	102 S
07 By window low	98 -	101 -	96 -	99 -
07 Main (on desk)	94 -	94 I	95 -	94 I
07 Main (over desk)	96 -	100 -	66 i	93 i
07 Records Rm	97 -	100 -	84 -	96 -
07 S.E.	100 -	114 S	100 -	104 S
07 S.E. (on desk)	100 -	98 -	100 -	99 -
07 S.E. [low]	100 -	243 S	43 -	133 S
07 Safe Rm	100 -	102 S	100 -	101 S
07 Safe Rm low	99 -	101 -	100 -	100 -
07 Storage	99 -	94 -	100 -	98 -
12 LA SE	100 -	150 -	100 -	114 -
12 LA West	100 -	147 S	100 -	113 S
12 Land Titles	100 -	104 -	95 -	100 -
12 Reception Area	100 -	101 -	100 -	100 -
13 Storage	99 -	95 I	69 i	94 I
13 Storage [low]	100 -	99 -	100 -	100 -
15 Accounting	100 -	103 -	100 -	101 -
15 Accounting [low]	97 -	99 -	90 -	97 -
15 EMO	100 -	102 -	100 -	101 -
15 EMO low	97 -	101 -	100 -	99 -
15 Entry	100 -	93 -	82 -	95 -
15 Entry [low]	85 -	110 S	81 -	92 S
B Back Drafting	100 -	108 -	100 -	102 -
B Below Kit	100 -	107 -	94 -	101 -
B Below Kit [low]	100 -	99 -	94 -	99 -
B Copier [low]	98 -	104 -	96 -	99 -
B Main Mid	98 -	99 -	99 -	98 -
B Main Mid [low]	100 -	96 -	99 -	99 -
B S.E. side	100 -	99 -	100 -	100 -
B Surveys (high)	97 -	93 -	88 -	95 -
B West end	100 -	100 -	100 -	100 -
Kitchen Main	93 -	104 -	99 -	97 -
Kitchen by Hood	99 -	94 -	71 i	94 i
Kitchen in hood	100 -	101 -	100 -	100 -
Main Air Intake	100 -	67 I	100 -	91 I
Main Intake Water #1	100 -	91 I	100 -	97 I
Main Intake Water #2	100 -	85 I	44 i	88 I

4.3.11 Manitoba Archives and Royal Visit Office

The Manitoba Archives Building is an older building specially modified for the storage of old historically important documents. The air is filtered, and maintained at constant temperature and humidity, with a high ventilation rate. No effects were detected in this building (Table 4-23). No health complaints were reported in the tested part of the building.

The Royal Visit Office was a small basement office in an older building, temporarily rented by the provincial government to coordinate plans for a visit by the Queen. There were numerous health complaints from the individuals working in this office, and tests indicated inhibitory materials associated with stained areas of carpeting, ceiling tiles, and near a reconditioned dry-process copier.

TABLE 4-23. MANITOBA ARCHIVES AND ROYAL VISIT OFFICE
ABSORBENT SAMPLER

SAMPLE	SURVIVAL	GROWTH	MATURE	FITNESS
Manitoba Archives:				
Archives cool rm	95 -	100 -	100 -	97 -
Cool Rm by Vent	100 -	98 -	100 -	99 -
Cool Rm old	100 -	100 -	100 -	100 -
HBA by intake	98 -	94 -	100 -	97 -
HBA new	97 -	97 -	96 -	97 -
HBA very old	90 -	101 -	93 -	94 -
Micrographics #1	98 -	101 -	99 -	99 -
Micrographics #2	98 -	100 -	100 -	99 -
Micrographics #3	100 -	102 -	100 -	101 -
Post Office	100 -	100 -	100 -	100 -
Printers Offset	98 -	100 -	100 -	99 -
Printers West	100 -	101 -	100 -	100 -
Printers by Mach.	93 -	99 -	95 -	95 -
Royal Visit Office:				
Coffee Room[low]	100 -	98 l	100 -	99 l
Copier (behind)	99 -	102 -	100 -	100 -
Copier (high)	100 -	92 l	73 -	94 l
End Office[low]	98 -	97 -	84 -	96 -
Entry	100 -	101 -	90 -	99 -
Exec. Office	96 -	85 -	100 -	93 -
Hallway	95 -	99 -	56 i	91 i

4.3.12 Other Locations

Table 4-24 reviews several other locations at which samplers had been used for air evaluations.

Tests were performed with absorbent samplers at a restaurant in a large department store. Toxic effects were detected in the air line of the cooking fume hood and in the designated smoking area.

A print shop had toxic effects by the printing presses, and showed stimulation in paper storage areas. Tests were carried out in a small shop in which dry copiers are serviced and repaired. Only one of each type of sampler was placed in this shop, and only the particle sampler detected inhibitory effects.

In an environmental laboratory, carrying out chemical tests for various contaminants, inhibition was detected in a room rich in ammonia vapors. Stimulation was found in a gas chromatography preparation room. No effects were identified in a PCB testing laboratory or in a small office.

On a recent trip to Los Angeles, samplers were opened in the aircraft (3 hours), in a hotel room (14 hours), and

on a balcony exposed to outside air (12 hours). No effects were detected.

The office over a printshop is in an older 2-floor wood-frame building, with numerous worker complaints. The one site examined in this office was stimulatory.

No significant effects were detected after a 3 day exposure period in an underground parkade.

TABLE 4-24. VARIOUS TESTED LOCATIONS

SAMPLE	SURVIVAL	GROWTH	MATURE	FITNESS
A. Restaurant:				
Back Kitchen	100 -	102 -	87 -	99 -
Dining -no smoking	100 -	99 -	86 -	98 -
Dining -smoking	100 -	103 -	59 i	95 i
In Cooking Hood	90 -	93 I	84 -	90 I
Main Kitchen	100 -	104 -	100 -	101 -
Over Cooking Hood	98 -	101 -	100 -	99 -
Staff Lounge	100 -	99 -	78 -	97 -
B. Print Shop:				
Darkroom	100 -	108 S	100 -	102 S
Machines	96 -	87 I	74 -	90 I
No Machines	99 -	110 S	100 -	102 S
No Smoking	100 -	103 -	98 -	101 -
Over Copier	100 -	106 S	100 -	102 S
C. Environmental Lab:				
Ammonia Rm	94 -	84 I	11 i	79 I
GC Prep	100 -	122 S	100 -	106 S
PCB Test Rm	100 -	93 -	44 i	90 i
Room 155	100 -	93 -	80 -	95 -
D. Copier Shop:				
Shop - Absorbent Sampler	100 -	108 -	80 -	99 -
Shop - Particle Sampler	94 -	84 I	31 i	82 I
E. Los Angeles Trip:				
Balcony	100 -	97 -	100 -	99 -
Inside Hotel room	100 -	101 -	100 -	100 -
Inside plane	100 -	100 -	100 -	100 -
F. Office Over Printshop	96 -	111 S	100 -	101 S
G. Parkade:				
Lower Level	100 -	95 -	100 -	99 -
Upper Level	96 -	99 -	73 -	94 -

4.4. HOMES

Several homes were tested with both absorbent and particle samplers, as shown in Table 4-25.

Home A is an old home, presently rented by several graduate students. The house had been vacant for about 1 year, and there was extensive fungal growth and mildew in the house. The home had been cleaned and disinfected, but the effects can be detected with the absorbent sampler.

Home B was a UFFI house, in which the UFFI has been removed. No effects are detected. Homes F, G, and I (Table 4-26) are also UFFI homes, with foam removed, with no detectable effects.

Home C is a UFFI home, with foam still in the home, showing no effects with either absorbent or particle sampler.

Home D is a UFFI home, with foam removed, occupied by a man and his wife who have experienced severe respiratory problems since the foam was removed. Stimulatory effects observed with both absorbent and particle samplers suggested that there was extensive microbial contamination. Steaming

of the rugs and draperies has reduced the discomfort of the occupants. Samples of the new Thermax foam in the building was examined, and both core and surface samples from the insulation was inhibitory.

Two UFFI homes in the Ottawa area were examined. The samplers were sent to Mr. C. Shirtliffe, National Research Council,Division of Building Research, and returned to Winnipeg for extraction and analysis. The particle samplers placed in house #1 detected inhibitory material at all tested locations, while no effects were found in the other house.

Home E is a new "energy-efficient" home. The residents had complaints of difficulty in breathing or sleeping. Several sites showed inhibitory effects (Table 4-26). No corrective actions have been taken.

TABLE 4-25. HOMES - ABSORBENT AND PARTICLE SAMPLERS

SAMPLE	SURVIVAL	GROWTH	MATURE	FITNESS
HOME A				
Absorbent Sampler				
Basement	95 -	121 S	100 -	103 S
Basement [low]	100 -	125 S	94 -	106 S
Bedroom N.	100 -	113 S	100 -	104 S
Bedroom N. [low]	77 L	133 S	100 -	96 L
Bedroom S.	98 -	115 S	100 -	103 S
Bedroom S. [low]	98 -	115 S	67 -	98 S
Living Rm.	98 -	110 S	100 -	102 S
Living Rm. [low]	86 -	134 S	100 -	102 S
Particle Sampler				
Basement	100 -	98 -	91 -	98 -
Basement [low]	96 -	100 -	100 -	98 -
Bedroom N.	100 -	98 -	91 -	98 -
Bedroom N. [low]	100 -	101 -	100 -	100 -
Bedroom S.	100 -	92 -	81 -	95 -
Bedroom S. [low]	95 -	94 -	96 -	95 -
Living Rm.	97 -	94 -	99 -	96 -
Living Rm. [low]	100 -	88 I	56 I	90 I
HOME B				
Absorbent Sampler				
BR	100 -	100 -	100 -	100 -
Basement	100 -	98 -	91 -	98 -
LR	100 -	101 -	100 -	100 -
Particle Sampler				
BR	100 -	103 -	100 -	101 -
Basement	100 -	101 -	100 -	100 -
LR	100 -	101 -	93 -	99 -
HOME C				
Absorbent Sampler				
Child's BR	100 -	99 -	100 -	100 -
LR	98 -	100 -	98 -	99 -
LR [low]	100 -	100 -	100 -	100 -
Main BR	99 -	100 -	100 -	99 -
Particle Sampler				
LR	100 -	100 -	100 -	100 -
Main BR	100 -	101 -	96 -	100 -

Table 4-25 (continued)

SAMPLE	SURVIVAL	GROWTH	MATURE	FITNESS
HOME D				
Absorbent Sampler				
Basement	100 -	101 -	56 -	94 -
Basement[low]	100 -	97 -	56 -	93 -
Family Rm.	100 -	126 S	100 -	107 S
Family Rm.[low]	100 -	126 S	100 -	107 S
Living Rm.	100 -	113 -	100 -	104 -
Living Rm.[low]	100 -	127 S	100 -	108 S
Master Bedroom	97 -	84 I	59 -	88 I
Master Bedroom[low]	98 -	96 -	100 -	98 -
Particle Sampler				
Basement	97 -	106 -	100 -	100 -
Basement[low]	100 -	92 -	100 -	98 -
Family Rm.	97 -	107 -	100 -	100 -
Family Rm.[low]	100 -	113 S	100 -	104 S
Living Rm.	100 -	115 S	100 -	104 S
Living Rm.[low]	97 -	98 -	100 -	98 -
Master Bedroom	97 -	111 S	100 -	101 S
Master Bedroom[low]	97 -	107 -	100 -	100 -
10% Extract of Insulation				
Thermax Surface	100 -	80 I	100 -	94 I
Thermax Interior	100 -	90 I	60 -	91 I
UFFI HOMES				
Absorbent Sampler				
#1 2nd Flr [low]	100 -	98 -	100 -	99 -
#1 Kitchen	100 -	98 -	100 -	99 -
#1 Basement	100 -	104 -	100 -	101 -
#1 Basement[low]	100 -	101 -	100 -	100 -
Particle Sampler				
#1 2nd Flr [low]	100 -	98 -	47 I	92 I
#1 Kitchen	98 -	101 -	40 I	91 I
#1 Basement	93 -	95 I	61 I	89 I
#1 Basement[low]	100 -	100 -	69 I	96 I
Absorbent Sampler				
#2 Bedroom	97 -	95 -	100 -	97 -
#2 Dining Rm	100 -	99 -	100 -	100 -
#2 Dining Rm[low]	97 -	103 -	94 -	98 -
#2 Basement	95 -	97 -	98 -	96 -
Particle Sampler				
#2 Bedroom	94 -	101 -	90 -	95 -
#2 Dining Rm	96 -	98 -	100 -	97 -
#2 Dining Rm[low]	94 -	100 -	94 -	96 -
#2 Basement	97 -	101 -	87 -	97 -

TABLE 4-26. HOMES - ABSORBENT SAMPLERS ONLY

SAMPLE	SURVIVAL	GROWTH	MATURE	FITNESS
HOME E				
Basement	100 -	96 -	100 -	99 -
Dining Room	98 -	89 I	90 -	94 I
Games Room (attic low)	97 -	107 -	50 -	93 -
Games Room (attic)	98 -	106 -	100 -	101 -
Living Room	90 -	97 -	100 -	93 -
Living Room[low]	83 -	103 -	100 -	91 -
Main Bedroom	95 -	79 I	42 I	83 I
Main Bedroom (closet)	100 -	81 I	68 -	90 I
HOME F				
Basement	100 -	107 -	97 -	102 -
Dining Room	96 -	99 -	84 -	95 -
Upper Bedroom	98 -	103 -	70 -	95 -
HOME G				
Basement	98 -	107 -	92 -	100 -
Kitchen	100 -	105 -	100 -	101 -
Living Room	92 -	103 -	94 -	95 -
Living Room[low]	100 -	102 -	100 -	101 -
Upper Front BR	100 -	101 -	100 -	100 -
HOME H				
Add Main	100 -	100 -	100 -	100 -
Add Main [low]	100 -	100 -	100 -	100 -
Basement	100 -	100 -	100 -	100 -
Upper BR	100 -	100 -	100 -	100 -
UpperB R(closet)	100 -	100 -	100 -	100 -
Upper BR[low]	100 -	100 -	100 -	100 -
HOME I				
Basement	99 -	100 -	99 -	99 -
Child's BR	99 -	100 -	100 -	99 -
Living Room	100 -	100 -	100 -	100 -
Main BR	100 -	100 -	100 -	100 -

4.5 CONCLUSIONS

The results of these field tests demonstrate that the use of the passive samplers coupled to bioassays provides a means to evaluate the air quality at specific regions in homes and workplaces.

The passive sampler-bioassay system detected regions within all but one of the ten extensively studied buildings that contained materials in the air that produced biological effects, although in none of the extensively studied buildings did all sites tested contain materials that produce biological effects. This indicates a heterogeneity of indoor air previously unsuspected.

The majority of sites tested produced no biological effects. With the absorbent sampler, 221 of the 390 tested sites (56.7%) showed no effects, while with the particle sampler, 178 of the 269 tested sites (66.1%) produced no effects.

Where effects were detected, usually an obvious local source could be determined. These sources include regions of heavy cigarette smoking, regions near dry process copiers and other machinery, areas containing in solvent fumes, localized areas of microbiological contamination resulting

from water accumulation or contaminated materials, and areas somehow isolated from the general air circulation.

Often the biological effects detected could be ascribed to combinations of the types of causes listed above. The results suggest that each area studied is unique and that decreased indoor air quality can result from a multiplicity of causes.

The use of this method has led to recommendations for actions to correct indoor air problems. Where these recommendations have been followed, the problems have been either greatly reduced or eliminated.

Cost analyses indicate that the tests can be performed at a cost of $130 per pair of samplers. This cost includes preparation of the samplers, bioassays, and analyses.

This project has resulted in the development of a simple, yet cost-effective method for determination of air quality, that can be immediately applied to the analysis of problems of air quality in the workplace.

CHAPTER 5

USES AND LIMITATIONS OF SAMPLER-BIOASSAY SYSTEM

5.1. UTILITY OF THE SYSTEM

The passive sampler-bioassay system described in this report provides a cost-effective alternative to chemical analysis as a method for determining indoor air quality. The system provides an objective evaluation of the air quality, and appears to be a good predictor of regions of indoor air that produce increased health complaints.

The passive sampler is reproducible and sensitive; capable of detecting heterogeneity of air quality at different sites within a home or workplace.

In practice, the passive sampler-bioassay system can be used as a primary indicator of air quality problems, and the information provided can be used to establish the sources of the contaminants and to suggest corrective actions. The system is intended to provide an overall indication as to whether or not air quality problems exist and to rank the overall air quality over a series of areas within a particular structure.

The sampler-bioassay system developed here has a significant advantage in that samplers can be sent quickly to any place in North America, opened at the tested sites, resealed, and returned to Winnipeg for bioassay. This provides a significant cost advantage over more traditional methods where highly trained individuals were required to set up and measure individual air quality indicators on an on-site basis.

The system can discriminate between chemical and biologically based air quality problems, and between particulate and vapor-phase components of the tested air. Rather than evaluation of the levels of a single component of the air, this approach determines the combined effects of contaminants in the air.

5.2 DISADVANTAGE OF THE SYSTEM

The primary disadvantage of the system is the time required between setting up the samplers and receiving the analyzed results. With a 7 day sampling period, one day for extraction, one day to set up tests, four days for growth, and one day to read the growth results, the minimum time from set-up to results is two weeks.

The second disadvantage of the system is the potential for misinterpretation of the bioassay results. The test determines whether or not materials trapped in the air produce a *biological* effect. A direct measure of the effect of the air on *human health* cannot be extrapolated from the bioassay results. The data suggest that where biological effects are detected the *potential* for health complaints is increased. If the air contains material that produces a biological response, the quality of that air should be called into question because of the increased potential to produce health problems.

The sampler was designed to be used as an objective means for evaluating the overall quality of indoor air, not as a method for establishing risks to humans. It is hoped that the application of such a system can reduce risk, but

the primary measurements relate to biological, not human, consequences of indoor air contaminants.

The system cannot establish the effects or levels of a single contaminating compound, and so air quality determinations using the passive sampler-bioassay system are not driven by established compound-by-compound air quality guidelines or regulations, but rather evaluates the net effect of all the constituents of the air. Most individuals responsible for air quality in specific buildings prefer to focus on absolute levels of specific compounds.

5.3 FURTHER DIRECTIONS

The passive sampler-bioassay system described in this report should be considered to be a prototype, exploiting a new approach for monitoring indoor air quality. The studies reported here indicate the utility of this approach.

However, improved systems could be easily developed. For example a much more rapid sampler-bioassay protocol could be developed using an impinger sampler flushing air volumetrically though water, followed by bioassay with a very rapid bacterial bioassay such as the Microtox test. This would permit sampling and analysis to be done on the same day. However, such a system would require on site visits by operators, and would not lend itself to use at sites distant from the bioassay laboratory. A compromise system would use the passive samplers, which could be shipped to the test sites and returned to the bioassay laboratory, coupled to a more rapid bacterial indicator system.

The passive sampler-bioassay system described here must undergo more extensive field study, with more linkage between the results of the assay, corrective measures and health complaints, as outlined in Section 5.1.

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APPENDIX I

SURVEYS OF HEALTH COMPLAINTS AND INDOOR AIR

A-1.1 METHODS OF STUDY

Although the primary objective of the study was to develop an inexpensive method for evaluating air quality, studies were carried out to determine the extent and types of health complaints in offices in Winnipeg buildings, which were utilized as locations for field tests of the sampler protocol. In order to gain access to the individual workers within the buildings, however, several constraints were placed on Bioquest staff. Firstly, confidentiality had to be maintained, so that no reference could be made to name or specific location within a tested building. The linkage between a response either by health interview or by questionnaire and the specific individual could not be made. This means that although a specific site within a building was identified by the sampler-bioassay system as having air that produces a significant biological effect, the complaints of individuals at that site could not be determined. Nor can the levels of complaints be related to any other characteristics of the building or specific site within the building. However, the results of these health complaint evaluations do provide evidence for the need for methods of air quality evaluation.

Two methods were used to examine the degree and type of health complaints. Firstly, a questionnaire was developed for determining the perception of air-related health complaints by individuals working in these offices. Secondly, direct interviews were performed by medical students employed by Bioquest, to develop a set of medical histories of the complaintants. The questionnaire provides an indication of the number of individuals with air- related health complaints, and an indication of the perceived extent of the problem, while the interviews establish an impartial, but subjective, evaluation of the severity of such complaints.

Although these studies were limited to Winnipeg offices, there are no reasons why these results should not apply in general to large office complexes in Canada.

A-1.2. THE HEALTH QUESTIONNAIRE

The questionnaire, presented in Table A1-1, usually was administered by an interviewer/evaluator employed by Bioquest, but, in one office it was distributed by the union-management joint safety committee. The results in this latter case showed no significant differences from those administered by interviewers.

Prior to administration of the questionnaire, the interviewer was instructed to make the following statement:

> "Some individuals, in this workplace, have suffered from general health discomforts; most of these complaints have no known cause. To help investigate the possible presence or absence of these complaints, Bioquest International Inc. has developed this questionnaire to determine if there is something in the air causing these discomforts. We appreciate your assistance in answering these questions."

The results are entered into an IBM PC computer, and counts made of the various responses. The health complaints are grouped into broad groupings. Respiratory complaints include chest tightness, congestion, difficulty in

breathing, sneezing and sinus congestion. Head complaints include headaches, insomnia, dizziness fatigue/drowsiness, and nosebleeds. Eye complaints include eye irritation and difficulty with contact lenses. Skin complaints include discolored skin, dry or flaking skin or skin irritation. Digestive complaints were limited to nausea. Muscle complaints include aching joints and back pain.

An individual expressing complaints in any one of the symptoms of a group was considered to have complaints of that group. Heartburn and muscle twitching were considered placebo effects, not due to air quality. An individual expressing these placebo effects was not considered to be manifesting indoor air quality-related health complaints. Therefore, all the complaints of those individuals expressing placebo effects were not included in the counts of complaints.

Table A1-1: The Bioquest Questionnaire.

1. How long have you been in this office? Mos Yrs .

2. Do you have any general health discomforts? Yes or No?

3. Specific Health Complaints

0 - no discomfort 1 - mild discomfort
2 - moderate discomfort 3 - extreme discomfort

0 1 2 3	Aching joints	0 1 2 3	Heartburn
0 1 2 3	Back Pain	0 1 2 3	Insomnia
0 1 2 3	Chest tightness	0 1 2 3	Muscle twitches
0 1 2 3	Congestion	0 1 2 3	Nausea
0 1 2 3	Difficulty in Breathing	0 1 2 3	Nosebleeds
		0 1 2 3	Discolored skin
0 1 2 3	Noticeable odours	0 1 2 3	Dizziness
0 1 2 3	Problems wearing contact lenses	0 1 2 3	Sinus congestion
		0 1 2 3	Dry, flaking skin
0 1 2 3	Eye irritation	0 1 2 3	Skin irritation
0 1 2 3	Fatigue/drowsiness	0 1 2 3	Hearing problems
0 1 2 3	Sneezing	0 1 2 3	Headaches

Other: _____

4. When do these complaints occur?

____ Morning	____ Daily	____ Afternoon
____ Specific day(s) of the week		____ All day
____ No noticeable trends		

5. a) Do you experience any relief from these complaints when you leave work? Yes or No.
b) Do they persist at home? Yes or No.

6. When did this discomfort start? _____
What do you think started it? _____

Table A1-1. Bioquest Questionnaire (cont.)

7. Sources of Discomfort in the Workplace

Y or N	Too Hot	Y or N	Too Moist
Y or N	Too Cold	Y or N	Too Stuffy
Y or N	Too Extreme	Y or N	Too Much Smoke
Y or N	Too Bright	Y or N	Too Noisy
Y or N	Too Dark	Y or N	Bad Smells
Y or N	Too Dry	Other	

8. When do these discomforts usually occur?

____	Morning	____	Daily
____	Afternoon	____	Specific day(s)
____	All day	____	No noticeable trends

9. How have the health complaints and workplace discomforts affected your efficiency?

0 no change 1 very little 2 moderate 3 very much

10. Do you have any of the following?

Y or N	Cold/Flu	Y or N	Skin allergies/ Dermatitis
Y or N	Hay fever pollen allergies	Y or N	Other Allergies
Y or N	Sinus problems		

11. Do you smoke Tobacco? Yes or No
Amount/day

12. Do you feel any discomfort while near any office equipment?
Yes (specify) or No.

13. Do you have any suggestions as to the changes that could be made? Yes (specify)_____
_____ or No.

14. Generally speaking, how would you compare the air quality in your workplace with the air quality in you home?
1 much better 2 better 3 the same 4 not as good

15. How important do you consider the issue of air quality in your workplace?
1 very important 2 important
3 not very important 4 not important at all.

Evaluator's comments:

A total of 382 individuals, primarily in clerical positions, were interviewed. The results of these interviews are presented in Table A1-2. A total of 249 individuals (65%) had what were classified as real health complaints stemming from indoor air quality. Only 31 individuals (8%) of those surveyed expressed the placebo symptoms. Of these 249 individuals with complaints, 231 (93%) stated that their symptoms were relieved at home.

Of the 249 individuals with real health complaints, 84% had complaints of headaches fatigue or drowsiness (head complaints), 79% had respiratory complaints, 68% had eye complaints, and 55% had skin complaints. Sixteen percent had hearing problems, and no individuals expressed either digestive or muscular complaints. The average level of respiratory, eye, head or skin complaint was moderate.

Eighty eight percent of those interviewed felt that air quality in the workplace was not as good as in their homes. Only 10% felt that the air in their workplace was as good as that at home, and only 1 percent (4 individuals) felt that the air was better in the workplace.

Table A1-2: Results of the Bioquest Questionnaire.

Mean refers to the average level of discomfort reported
0:no effect 1:mild discomfort
2:moderate discomfort 3:extreme discomfort

Sample size 382 individuals.

TYPE	%	MEAN
Percent with Complaints	65%	
Respiratory	79	1.91
Head	84	1.91
Eyes	68	1.96
Skin	55	1.99
Digestive	0	0.00
Muscles	0	0.00
Hearing	16	1.78
Placebo	8	
Relief at Home	93	

Thirty five individuals (9% of those surveyed) stated that their health complaints had a great effect on their job performance, while 142 (37%) stated that there was a moderate effect on their job performance due to air quality. Thirty two percent of the respondents claimed little effect on job performance, and 22% reported no effect on job performance. However, all of the respondents claimed that air quality was important in the workplace.

Of the environmental features of the workplace causing discomfort, temperature and humidity were the primary sources of complaints (75% and 71%, respectively). Stuffiness and odors were also major sources of discomfort (65% and 58%, respectively). Only 17% complained of smoking, while 28% complained of poor lighting.

Seven different workplaces, each with 50-60 individuals were examined with the questionnaire. In the worst case, 95% of the respondents had health complaints, while in the best case 53% had health complaints. Table A1-3 compares the pattern of complaints in these two locations. Surprisingly, the pattern of complaints in these two locations is quite similar. This suggests a gradation of sensitivities in the population, in which under better conditions fewer people show the specific symptoms, but as the quality of indoor air deteriorates more people express

health complaints, rather than there being a distinct threshold of air quality, below which there are no complaints and above which there are health complaints.

Table A1-3: Questionnaire Results at two locations.

Location A (640 Corydon) represents the location with the lowest percentage of complaints. Location B (1200 Portage) represents the location with the highest percentage of complaints.

Mean refers to the average level of discomfort reported
0:no effect 1:mild discomfort
2:moderate discomfort 3:extreme discomfort

Sample size: Location A 62 individuals.
Location B 49 individuals

	LOCATION A		LOCATION B	
TYPE	%	MEAN	%	MEAN
Percent with Complaints	53		93	
Respiratory	85	1.92	82	1.94
Head	85	1.94	93	1.99
Eyes	70	1.95	80	2.02
Skin	54	1.86	63	2.07
Digestive	0	0.00	0	0.00
Muscles	0	0.00	0	0.00
Hearing	28	1.76	8	1.80
Placebo	9		2	
Relief at Home	97		91	

A-1..3. HEALTH INTERVIEWS

The results of the health interviews cannot be summarized quantitatively. Rather, a typical series of reports on complaints will be excerpted to indicate the types and degrees of complaints detected. These refer to a group of workers who had moved to a new location 18 months previously.

> "Evaluating the history of each health problem was not too difficult as almost all of them began immediately after arrival to the present location while others showed delayed onset manifestations. The majority of people are still performing the same job that they did at their previous location.... people complained of dry itchy skin (i.e. exposed skin), chest congestion with dry cough, dry airways, and painful itchy eyes. They also complained of "a pressure on my head" which in one woman lead to headaches and dizziness. Two women smoked cigarettes but had never suffered the tightness and congestion (or any of the other symptoms) at the previous location. One woman could obtain relief by going for a walk while the other continued coughing throughout the entire day and night."

"One woman had eczema diagnosed three months after arrival at the building. She had never had it before and only her father's father had a history of it. She had no allergies yet suffered sneezing attacks almost daily sometimes causing her to wheeze. Both the eczema and sneezing did not occur anywhere else but at work."

"Both people had the common complaint of daily afternoon headaches and drowsiness. Both are doing the same jobs as in the previous location, like doing them, and never had these symptoms before. Neither suffer these effects at home, weekends, or on holidays. Both felt their job performance was affected."

"One woman had suffered an eye irritation, received drops from doctor, eye did not heal and proceeded to ulcerate. She subsequently had to wear an eye patch."

"One office worker reported itchy skin (as did the open area workers) when in office for an extended period of time. This did not occur anywhere else or before moving to the present locale."

"Woman with a family history of Rheumatoid arthritis complained of intense chest pain, skin irritations (pimples, boils) headaches, fatigue, and weakness. These symptoms are chronic and they started about one year ago in this office. She had suffered a similar pain at her last job at a chemical plant. She also says that she feels the symptoms of a cold (congestion, malaise) while at work, but it clears up when she gets home. She feels that her vision is deteriorating (foggy at work) and her voice is very raspy. She finds herself now becoming nervous and depressed. She has been diagnosed as having chemical and mold allergies (leaking pipes were found behind a wall in the office), however, these only act up at work and not anywhere else (where they lead to wheezing and sneezing). She has missed an inordinate number of work days and sometimes comes into work for only two hours. By Sunday she feels fine, "like a new person," and by Monday noon the symptoms begin and slowly progress, worsening as the week goes on."

"A man with no history of headaches reported that when he has to spend a day in the office he suffers from headaches and fatigue which do not subside in the evening. He is going to see

a doctor for these complaints. His job allows him much travel and he does not suffer either of the symptoms anywhere else."

"All three workers in this area stated that they suffer eye burning and pain, fatigue, and excessive drowsiness. None of these symptoms occurred with the present consistency at the previous location on the first floor. They all described the afternoon drowsiness as "fighting to keep your eyes open." All felt their job performance was affected."

"Another employee, a fitness instructor, who conducts noon hour aerobics, suffers from wheezing and a tightness in her chest. She considers herself to be in good shape and these manifestations only occur on the third floor. She also says that she now has to go home and sleep for two hours every day after work, something she never did while working on the first floor. She also disclosed that she likes to wear contact lenses at all times (she hates wearing glasses) but lasts only one to two hours in the morning, at which time her eyes become glassy and bloodshot (she then has to wear glasses). A couple of time per week she has a numbness on the left side of

her face which immediately goes away when she leaves work. A doctor could not find a reason for this. Normally a calm, contented person, she now finds herself anxious and nervous at work."

"One woman, who works in a very hot office, has developed a chronic plugged nose which clears up at night. She definitely feels her concentration and productivity is hampered."

"Another woman described herself as having to "fight for Oxygen". She says her office undergoes variable temperature extremes. Her job requires her to read, analyze, and write, but in the afternoon the eye burning and fatigue set in and she has to take her work home or do it the next morning. This began right after the move from the first floor. She has no allergies but complained of a chronic congestive cold."

"Another woman, with an allergy to metals, reports intense red burning eyes which start on Monday worsen by Friday clear by Sunday (she must use eye ointment seven times a day). She has a history of skin boils but has suffered an increased number of them since the move."

"A woman who began work in the office in July of 1984 began in March to manifest the symptoms of red itchy lumps on her face which to date have not cleared up. She has also twice had a chemical irritation of her gums and is presently under the care of a periodontist. She has also noticed a lesion on the white of one eye."

"Another woman, in addition to a similar lesion in her eye, has a permanent red streak in one eye which fails to appear when she is away from work for an extended period of time. She has no allergies, yet every day upon arrival to work she becomes congested and suffers sneezing fits. For relief she steps outside and immediately becomes cleared up. She comes back in and the symptoms start again. She takes antihistamines which sometimes work. At the previous location she was always ahead in her work but since the move is always behind. The workload and job pressure have not changed and she says it is "impossible to do a full day's work"."

"Three times over the past year a woman noticed a boil on her neck which took an excessively long time to heal. She also cannot keep her contact lenses in for the whole day

because they keep drying out. She has a family history of migraines but feels she is getting far too many since the move. Her fatigue continues into the evening and has affected her home life (her husband has noticed a change in her). She feels her job has no more pressure than it ever has but has noticed herself change at times from a contented and relaxed individual to one experiencing bouts of nervousness and depression."

"Granted that some people like to complain, if there is someone to complain to, and people would like their working conditions to be 'perfect', but the numbers, types, and severity of the manifestations reported are more than convincing enough to tell me that there is a real problem here."

These reports give an indication of the kinds and degree of health complaints resulting from poor indoor air quality. Often the complaints are subtle and very subjective. However, our interviewers have been convinced that the majority of complaints are real, are based on workplace air quality, and do have an adverse impact on job performance.