RESEARCH REPORT

Assessment of the Indoor Air Quality of a Suite for an Environmentally Hypersensitive Occupant

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Assessment of the Indoor Air Quality of a Suite for an Environmentally Hypersensitive Occupant

Submitted to:
Research Division
Canada Mortgage and Housing Corporation
700 Montreal Road
Ottawa, Ont.

CMHC Project Manager: Virginia Salares

Submitted by
Sheltair Scientific Ltd
2-3661 West 4th Ave
Vancouver, B.C.
V6R 1P2
tel (604) 732-9106
fax (604) 732-9238

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Abstract

This report documents the design and construction of an Environmentally Hypersensitive (EH) suite within a conventional apartment building, and how it differs from a conventional unit in the same building. The indoor air quality of the EH unit was monitored, and compared with that of the conventional unit and the outdoor air quality. Analysis was conducted once prior to occupancy and twice after occupancy of the units. An interview with the occupant of the EH unit was conducted to document the tenant's satisfaction and compatibility with the unit.

The measurements showed lower formaldehyde levels and higher ventilation rates in the EH suite compared to the conventional unit. The EH suite was less leaky in terms of air tightness. The TVOC measurements were not definitive. Further measurements are needed to ascertain if chemical contaminants are being brought into the unit.

The tenant reported incremental improvement in the unit compared to her previous residence.

FOREWORD

At the present time, there is a pressing need for housing that would be suitable for individuals who are environmentally disabled. While those who own their homes may be able to make changes to improve the quality of the air in their dwellings, others who rent are unable to find appropriate accommodations that provide clean air.

In 1993, the first social housing project for individuals who suffer from environmental hypersensitivity, the Barrhaven Multi-Unit Housing Project, was built in Nepean, Ontario. Though the building provides housing for only seven families/individuals, just a tiny dent on the population in need of clean housing, the construction of this building was a significant milestone. It represented an acknowledgement of the need for such housing.

A special unit in an apartment complex in Victoria, BC is the second attempt at providing clean air housing for the environmentally hypersensitive. One of the units in the building was modified for this purpose. The project was funded jointly by a federal and a provincial program with the lead role by the Capital Region Housing Corporation.

Is it possible to designate, with suitable modifications, one unit of an apartment building as a clean air unit? This study is an evaluation of such a project. It compares the indoor air characteristics of this unit with a comparable conventional unit and evaluates the level of satisfaction of the occupant with the unit.

It is important to know whether efforts to build clean air units are successful or not. The lessons learned from pioneering efforts such as this one can only improve future endeavours.

Virginia Salares
Research Division, CMHC
700 Montreal Road
Ottawa, Canada K0A 2H0

Tel. (613) 748-2032
Fax (613) 748-2402

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Summary

This project analyzes and documents the findings of a comparative case study between an environmentally hypersensitive (EH) suite and a conventional suite in a newly constructed apartment building, located in Victoria, BC. This report documents the design and construction of the EH unit, and how it differs from a conventional unit in the same building. The indoor air quality of the EH unit was monitored and compared with that of the conventional unit and the outdoor air quality. Analysis was conducted once prior to occupancy and twice after occupancy of the units. An interview with the occupant of the EH unit was conducted to document the tenant's satisfaction and compatibility with the unit.

There was considerable effort made in designing the EH suite, and for the most part, the suite works well. Although improvements could be made in the design of the EH suite, the most significant improvements in design could be in how the suite might be incorporated in the larger design of the apartment block in order to promote integration of the occupant without compromising the occupant's health.

VOC's, formaldehyde, mold, dust and air change effectiveness were measured and compared between the EH suite and the conventional suite. The measurements showed lower formaldehyde levels and higher ventilation rates in the EH suite. The EH suite was less leaky in terms of air tightness. The results of the TVOC measurements were not definitive. Further measurements are needed to ascertain if chemical contaminants are being brought into the unit.

The EH suite at the Selkirke Apartments provides the occupant with an indoor air quality that is incrementally better than her previous accommodation. While the situation is by no means perfect for the occupant, she is coping better with her condition. If one uses the criteria of incremental improvements in order to assess the success of the EH suite, one may conclude that it is successful.

Évaluation de la qualité de l'air intérieur d'un logement aménagé à l'intention d'un occupant hypersensible aux polluants environnementaux

Résumé

Ce rapport analyse et documente les résultats d'une étude de cas comparative portant sur un logement pour occupant hypersensible aux polluants environnementaux (logement pour O.H.) et un logement traditionnel situés dans un immeuble d'appartements de Victoria, en Colombie-Britannique. On trouvera dans ce rapport une description de la conception et de la réalisation du logement pour O.H. ainsi qu'une explication de ce qui le différencie d'un logement traditionnel situé dans le même immeuble. On a contrôlé la qualité de l'air intérieur du logement pour O.H. et on l'a comparée avec celle du logement traditionnel et avec la qualité de l'air extérieur. L'analyse a été réalisée une fois avant l'occupation des logements et deux fois après leur occupation. L'occupant du logement pour O.H. a été interrogé afin de documenter sa satisfaction et sa compatibilité avec le logement.

On a fait des efforts considérables pour aménager le logement pour O.H. et, dans l'ensemble, les mesures prises sont efficaces. Bien que des améliorations conceptuelles pourraient être apportées au logement pour O.H., les améliorations conceptuelles les plus importantes consisteraient à déterminer comment on pourrait mieux incorporer le logement au sein de l'immeuble d'appartements afin de favoriser l'intégration de l'occupant sans compromettre sa santé.

Les composés organiques volatils, le formaldéhyde, les moisissures, la poussière et l'efficacité du renouvellement d'air ont été mesurés dans les deux logements à l'étude puis comparés. Ces mesures ont fait état de concentrations de formaldéhyde plus faibles et de taux de ventilation plus élevés dans le logement pour O.H. comparativement au logement traditionnel. Le logement pour O.H. présentait moins de fuites d'air. Les mesures de la concentration totale en VOC n'étant pas définitives, d'autres mesures devront être prises afin de déterminer si des contaminants chimiques sont admis dans le logement.

Le logement pour O.H. de l'ensemble Selkirke Apartments offre à l'occupant une qualité de l'air intérieur graduellement meilleure que dans son logement précédent. La situation n'est certes pas parfaite pour l'occupant, mais son nouvel appartement lui permet de mieux composer avec son état. Si l'on retient le critère d'amélioration graduelle pour évaluer le succès du logement pour O.H., on pourra conclure que l'expérience a été fructueuse.

National Office
700 Montreal Road
Ottawa ON K1A 0P7
Telephone: (613) 748-2000

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700 chemin de Montréal
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Introduction: Project Scope

Indoor Air Quality (IAQ) is a complex interaction of many constantly changing factors. The driving forces leading to IAQ problems include inadequate ventilation, coupled to an increase of pollutant sources in new buildings. There are hundreds of pollutants that affect IAQ, and thousands of sources. The health impacts associated with IAQ are especially acute in the case of Environmentally Hypersensitive (EH) occupants, and depend on a number of factors related to the toxic substance, the dose, the environment and the occupant.

Key Factors Affecting the Hazards posed by Toxic Substances

Substance	**Dose**
• Chemical properties • Physical properties • Toxicity	• Concentration • Duration of exposure • Route of entry
Environment	**Occupant**
• Temperature • Humidity • Light and noise levels • Pressure differences • Presence of other contaminants	• Genetics • Gender • Age • Personal Habits • Diet • Health status

Because of the complexity of the cause and effect chains leading to EH health problems, the documentation of case studies provides an important means of assessing the current state of air quality in EH units and an opportunity to improve the performance of future designs. Therefore, the current project is seen as an important exercise to characterize the performance of an EH unit, and to correlate that information to the needs of current and future EH occupants.

Project Objectives

The objective of this project is to analyze and document findings of a comparative case study between an environmentally hypersensitive suite and a conventional suite in an apartment building. Specifically, this report

1. Documents the design and construction of the EH unit, and how it differs from a conventional unit in the same building.
2. Present the results of monitoring the indoor air quality of the EH unit, in comparison with that of a conventional unit and the outdoor air quality. Analysis was conducted once prior to occupancy and twice after occupancy of the units.
3. Provides results of an interview with the occupant of the EH unit, and documents the tenant's satisfaction and compatibility with the unit.

Chapter 1: Housing for the Environmentally Hypersensitive: A Brief Overview

Definition

The following definition of environmental hypersensitivity is taken from the Thomson Report on Environmental Hypersensitivity disorders:

> "Environmental Hypersensitivity (ecological illness) is a chronic (i.e. continuing for more than three months) multi-system disorder, usually involving symptoms of the central nervous system (CNS) and at least one other system. Affected persons are frequently intolerant to some foods and they react adversely to some chemicals and to environmental agents, singly or in combination, at levels generally tolerated by the majority. Upon examination, the patient is normally free from any abnormal objective findings."[1]

Characteristics and Causes

A person who is suffering from environmental hypersensitivity reacts intensely to infinitesimal exposures of pollutants, toxic and seemingly banal substances. The symptoms of environmental hypersensitivity vary considerably from one person to another, and are often multiple. Symptoms may occur anywhere in the body, internally or externally. Further, the health care community is still in the process of determining the full extent of housing related health effects. Treatment for environmental hypersensitivity consists mainly of avoidance. As one author explains "One useful rule to follow is: if it smells, avoid it... A second useful rule is: if you can live without it, avoid it, and give your body time to heal with less stress."[2]

A number of factors have been cited in the literature to contributing to environmental hypersensitivity. These include genetic characteristics, nutritional state, total biological and chemical stressors, chronic exposure to low levels of stressors, acute exposure to high levels of stressors, and illness, infection and stress level.

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[1] The Office of the Deputy Minister of Health of Ontario, Report of the Ad Hoc Committee on Environmental Hypersensitivity Disorders, Ontario Ministry of Health, Toronto Ont., 1985

[2] Rea, W.J., "Ecological Illness: Maladaption to the Environment", Human Ecology Foundation Canada Quarterly, Vol. X, No. 1, pp. 3 - 5, March 1988

Housing

A number of components and assemblies within a house have been identified as producing significant levels of chemical pollution. The following list provides a few of the items commonly found in the construction of a home, which may cause an adverse reaction in an environmentally hypersensitive occupant.

gas and wood combustion appliances (stove, dryer, hot water tank)
plastics of all kinds
synthetic fibres (nylon, dacron etc.) and chemical treatments
paint fumes
vinyl wall paper and adhesives containing fungicides
synthetic carpets
cabinets and furniture constructed with formaldehyde based glues
linoleum
asphalt roofing
vinyl siding
exposed insulation
pine and cedar paneling
adhesive fumes.

In existing houses, molds are a concern. The health effects of molds potentially effect everybody, especially sensitive individuals.

Where to go for Help

There are a number of publications related to environmental hypersensitivity and housing which may provide the reader with guidance. Of particular interest are three recently published CMHC documents.

The Clean Air Guide [3] provides information on how to identify, evaluate and deal with indoor air quality problems in the home. The guide provides a list of organizations and resources for people who suffer from environmental hypersensitivity. In addition, the guide provides a selected list of works available on the health related impacts of housing. Finally, the guide presents a list of features that are common to homes that have been built for health reasons.

This Clean House Video[4] compliments The Clean Air Guide. In this video, a typical house with an asthmatic occupant is toured with an indoor air quality expert.

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[3] The Clean Air Guide, Canada Mortgage and Housing Corporation, Ottawa, Ont., Canada 1993
[4] This Clean House Video, Canada Mortgage and Housing Corporation, Ottawa, Ont., Canada, 1994

Building Materials for the Environmentally Hypersensitive[5] was written to help individuals and builders select materials that have a minimal adverse impact on the health of environmentally hypersensitive occupants.

Housing for the Environmentally Hypersensitive[6] provides an extensive investigation of 12 case study buildings constructed or modified to meet the requirements of environmentally hypersensitive occupants. The case studies document architectural, mechanical, electrical and plumbing features of the building, describes the costs of the features, and provides an anecdotal assessment of how well the building meets the occupants' needs. The report also includes information on controlling indoor air quality, and provides general information to reduce the emission of pollution and improve ventilation.

Evaluation of the Barhaven Multi Unit Housing for the Environmentally Hypersensitive [7]is a study that documents a post-occupancy evaluation of a multi-unit housing project for the Environmentally Hypersensitive.

Housing Needs of the Environmentally Hypersensitive: Socioeconomic Health Factors[8] surveys two hundred environmentally hypersensitive individuals to gather information on family characteristics, economic status, housing needs and preferences.

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[5] Building Materials for the Environmentally Hypersensitive, Canada Mortgage and Housing Corporation, Ottawa, Ont., Canada., 1996.

[6] Housing for the Environmentally Hypersensitive, Canada Mortgage and Housing Corporation, Ottawa, Ont., Canada, 1990

[7] Evaluation of the Barhaven Multi Unit Housing for the Environmentally Hypersensitive, Canada Mortgage and Housing Corporation, Ottawa, Ont., Canada, 1996

[8] Housing Needs of the Environmentally Hypersensitive: Socioeconomic Health Factors, Canada Mortgage and Housing Corporation, Ottawa, Ont., Canada, 1997

Chapter 2: Case Study of the Environmentally Hypersensitive and a Conventional Suite

This chapter describes the environmentally hypersensitive suite, and details the design features which distinguish the EH suite from the rest of the apartment building. The architectural and mechanical features of the EH suite are contrasted to the conventional suite.

General Description of Project

The EH suite is a unit built on the ground floor of a three storey multi-family apartment block. The apartment is located in Victoria, BC, on a site that was previously zoned for industrial use. The apartment block was built for and is managed by the Capital Region Housing Corporation (CRHC). The CRHC is a public institution providing affordable accommodation to people in the Capital Regional District. The Building was completed in September 1996, and the Environmentally Hypersensitive unit was first occupied in February, 1997.

The apartment building is wood frame construction with an underground parkade that is typical of many apartment buildings on the West Coast. Drawings of the EH and conventional suites are presented in Appendix 1. Both suites have one bedroom and are located on the ground floor of a three floor structure. The floor area of the EH suite is 59.7m^2, while the conventional suite has a floor area of 43.8 m^2.

Architectural features of the EH suite.

There are a number of features which distinguish the EH unit from the conventional unit. At the design stage, an additional set of specifications documents were developed by the project architect to:

- isolate the EH suite from external and inter suite sources of contaminated air; and,
- describe a range of materials and procedures to minimize or eliminate hazardous sources from within the suite.

Isolation of ventilation air from the rest of the apartment

A number of strategies were incorporated into the design of the EH suite in order to isolate the ventilation air for the EH suite from the rest of the apartment building. For example,

- the EH suite was designed to be more air tight than the other suites. The suite was designed with an airtight drywall system as well as an interior air/vapour barrier system.

- The EH unit has an entrance accessed directly from outdoors, whereas, the other apartments have access via a central apartment corridor

Materials choice for the EH Unit

A number of design choices were made in order to reduce the generation of dust and the off-gassing of VOCs and formaldehyde from the construction materials used in the EH suite. In particular:

- All concrete products used inside the airspace were free of fluidizers, plasticizers, surfactants and retarders.
- No formaldehyde bonded or treated wood products were used inside the airspace of the EH suite. However, the floor joists of the EH suite were constructed with engineered I joists with webs of oriented strand board. To reduce off-gassing from this material, the I joists were painted with ultra low odor paint. The sub-floor was constructed of exterior grade plywood, and no construction adhesive was used in laying the floor.
- Cabinets and shelving were constructed of formaldehyde free medite and exterior grade fir plywood. Cabinets were finished with melamine and high pressure laminates. For bonding cabinets and shelving parts, white carpenters glue was used. All exposed surfaces were painted with ultra low odor paint.
- Interior trim was made from finger jointed hemlock and fir, and finished with low odor enamel.
- Insulation in the suite is fiberglass batt. The air/vapour barrier was constructed with polyethylene sheet with the seams taped using builders tape.
- Siliconized latex caulking was used for sealing around plumbing and electrical fixtures, and window openings. No acoustic caulking or solvent type caulking was used.
- The weather barrier is polyolefin sheet material, joined using builders tape. No asphalt treated paper was used around the EH Suite.
- All interior walls and ceilings were finished with air-tight drywall using gypsum wall-board and a PVC gasket. Wall and ceilings were painted with low emission paints.
- Ceramic tiles were used on the floor throughout the EH suite and for the back splash in the bathroom. The tiles were fixed with thin set mortar, and grouted with sanded floor tile grout. No carpet, sheet vinyl or rubber-based floor coverings were used.
- Plumbing fixtures are enamel steel. Fiberglass and acrylic fixtures were not suitable .

For a detailed description of building materials suitable for the environmentally hypersensitive, the reader is referred to CMCH[9].

The conventional suite was built to current practices. Finishes and sealants are those used in normal construction practices. Most noticeably, the floors were finished with carpet and linoleum. In addition, cabinets or shelving are made of particle board. The unit does not have its own heat recovery ventilator. Ventilation air is provided by air supplied to the common corridor.

General observations about the architectural design

There was considerable effort made in designing the EH suite, and for the most part, the suite works well. Although improvements could be made in the design of the EH suite (a central vacuum cleaner with exhaust to outside, for example), the most significant improvements in design could be in how the suite might be incorporated into the larger design of the apartment block in order to promote integration of the occupant without compromising the occupant's health.

There seems to be insufficient recognition that the walls of the EH suite do not form the boundaries of what affects the occupant of the suite. Significant stressors are imposed on the occupant of the EH suite from sources that are exterior to her suite. For instance, there is a family laundry room located about 5 meters from the entrance to the EH unit. The exhaust from the dryer vent is located across a walkway from the EH unit, and the smell of laundry detergent and fabric softener was quite noticeable around the entry to the EH suite. In response to this problem, the occupant of the EH suite has had to tape her door shut to eliminate the entry of contaminated air. Additional examples of short-comings of how the EH suite was incorporated into the larger design include:

- a court yard in front of the EH suite that is used by people smoking cigarettes, and
- cedar bark mulch used for landscaping the patio area.

Ventilation and mechanical description of the Suites

There are a number of differences in design of the mechanical systems between the EH unit and the conventional unit. The EH suite has Intertherm liquid filled electric baseboard heaters in the bedroom and living room. A Lifebreath heat recovery ventilator with a Scrubber brand air filter is used to provide ventilation. The HRV has been balanced using balancing dampers, and all ducting is rigid galvanized steel that has been washed with a mild solution of washing soda (sodium carbonate). The design specified that all joints were to be

[9] Op Cit [5].

sealed with foil heating tape, and the use of plastic duct tape and plastic sealers was avoided in the ducting.

The EH unit has three ventilation fans, one is located in the bathroom, and the other two are in the kitchens. The fans in the kitchen are a range hood fan located above the stove, and a second fan located above the oven. All fans are vented directly to outside. Flow rates for the ventilation equipment are presented in the section on Results of testing. Outside air for the HRV is supplied through an 8 inch duct from the roof. The HRV air intake is approximately 3 feet above the roof of the building. The roof is constructed of modified asphalt torch-on. The exhaust air from the HRV is ducted laterally to the outside. The 4 vents for the HRV and exhaust fans are located above the bedroom and living room windows of the EH unit.

The supply and exhaust diffusers were located within the suite to maximize ventilation effectiveness and to mitigate the stressors created by the suite occupant. For example, the exhaust diffuser in the bedroom of the EH unit was located in the closet to ensure that pollutants from clothing would be picked up and removed from the room.

The conventional suite is heated with a forced air heating system. A gas fired heating unit located on the roof supplies heat to a fan coil in the corridor pressurization system. Ventilation air is supplied from the corridor pressurization unit. The suite has bathroom and kitchen ventilation fans.

General observations about the ventilation and mechanical systems

A potential problem in the design of the ventilation system of the EH unit is that the suite is slightly depressurized relative to the rest of the apartment building by approximately 5 Pa. When the exhaust fans are operating in the EH suite, the pressure difference between the EH suite and the rest of the apartment increases to as much as 30 Pa. This means that contaminated air will tend to flow into the EH suite from the rest of the apartment through leakage paths detected as part of this study.

A number of observations were made about the ventilation systems.

- The ducting from the stove fan was not well sealed, and there was considerable leakage through the ducting. This may be a problem when trying to exhaust fumes from the area around the stove.
- The fans in the EH suite are vented directly. When in operation, this leads to depressurization of the suite by 20 to 30 Pa. Instead of being direct vented, these exhaust could have been integrated with the HRV as part of a balanced ventilation system.

- Because the distance between the roof and the HRV intake is approximately one meter, there is the possibility that intake air may be picking up volative chemical emissions from the asphalt roof.
- A number of small leaks were detected in the ducting to and from the HRV.
- The exhaust vents for the HRV, and suite fans are located in a recess of the exterior wall above the bedroom windows. With the windows open and a wind from the south, there is the potential for re-entry of exhaust air into the suite.

Chapter 3. Indoor Air Quality Measurement Methodology

Testing of the EH unit, the conventional suite and outdoor air was performed to assess the IAQ of the EH suite and compare it to a conventional suite in a multi-unit building. Testing occurred three times over a span of eight months. Environmental and chemical factors related to potentially toxic substances were measured once before occupancy in November, 1996, and twice after occupancy (March and June, 1997). Factors affecting the effectiveness of the ventilation system were measured prior to occupancy only. The parameters that were measured is summarized in Table 1. A description of the testing methodology employed in the analysis is reviewed below.

Table 1: Summary of Measurments

Parameter	Location of Measurements	EH Suite			Conventional Suite		
		Nov.	Mar.	Jun.	Nov.	Mar.	June.
Temperature	Living room	yes	no	yes	yes	no	no
Relative Humidity	Living room	yes	no	yes	yes	no	no
Carbon Dioxide	Living room	yes	no	yes	yes	no	no
Carbon Monoxide	Living room	yes	no	yes	yes	no	no
VOC	Living room	yes	yes	yes	yes	yes	no
Formaldehyde	Living room	yes	yes	yes	yes	yes	no
Dust	Living room	yes	no	yes	yes	no	no
Mold	Kitchen, Living room, Bathroom, Bedroom and Outside	yes	no	yes	yes	no	no
Ventilation Effectiveness	Kitchen, Living room, Bathroom and Bedroom	yes	no	no	no	no	no

Temperature, Relative Humidity, Carbon Dioxide and Carbon Monoxide

Temperature, Relative Humidity, Carbon Dioxide and Carbon Monoxide were monitored continuously for 24 hour samples using a YES model 765-204 multi-channel analyzer. Carbon dioxide was measured with a non-dispersive infrared

CO2 optical diffusion gas cell. The temperature sensor employs a negative temperature coefficient thermister. The relative humidity was measured with a capacitive thin polymer film. The carbon monoxide sensor used an electrochemical sensor with a range of 0 to 50 ppm. Measurements were taken in the EH unit, the conventional unit and outdoors. Data was logged onto a computer, and trend analyses were developed.

Formaldehyde

Sampling and analysis of formaldehyde were conducted in accordance to NIOSH method 3500. Formaldehyde samples were collected using a calibrated air pump passing controlled volumes of air through a sodium bisulphite trapping solution over a measured interval of time. Sampling occurred prior to occupancy, one week after occupancy and again four months after occupancy in the EH suite. Sampling was also performed prior to occupancy in the conventional suite. The samples were analyzed in a laboratory using a colourimetric procedure to obtain formaldehyde concentration estimates. Results are expressed in total formaldehyde concentration in parts per million (ppm).

Total Volatile Organic Compounds (TVOCs)

The TVOC sampling employed two passive sampling techniques. An activated charcoal sampler[10] was used in the EH and conventional suites before and after occupancy. In addition, a 3M passive sampling badge was used to collect TVOC concentrations in the EH and conventional suites after occupancy. Both samplers employ a passive diffusion technique. Organic compounds enter the monitor by diffusion, and are absorbed by an active charcoal absorbent. The samplers were sent to the University of Manitoba for analysis. A gas chromatrograph was used to obtain the amount of VOC absorbed by the sampler The amount of absorbed VOC, together with the sampling time and the diffusion sampling rate are used to calculate the TCOC concentration present in the sampled indoor environment.. Results are expressed in total volatile organic compounds per unit volume (mg/m^3).

Molds

To obtain information on the concentration and species of molds, an RCS sampler with agar strips was used. Multiple samples were collected in the EH and conventional units. Specifically, samples were taken in the bedroom, the bathroom and the living room/kitchen areas. In addition, samples were taken

[10] Passive Monitors for Organic Pollutants in Indoor Air, Canada Mortgage and Housing Corporation, Ottawa, Ont., Canada, 1997.

outside the building. The mold samplers were sent to the University of Alberta for identification.

Airborne Particulates

Airborne particulates were measured continuously using a Grimm model 1.105 dust monitor. Atmospheric dust concentrations were measured by passing a controlled volume of air through an optical bench. When particles pass through a beam of light, this causes the light to scatter. A photo diode generates a signal by measuring the amount of scatter. A pulse height analyzer processes this signal. The monitor is capable of providing a data log of particulate mass distribution and counts for particles ranging in size from 0.5 μm to 15μm.

Air Change Effectiveness

The purpose of this test was to measure the effective air change rates in the EH suite and the conventional suite. The test procedure is based on ASTM Standard E 741 (1983). The test utilized a 5-sensor Halitec F01 - 5 and R134A tracer gas. The tracer gas was released in the suite and the concentration of gas was measured at one minute intervals over an eight hour period. The tracer gas concentration decay curve was used in conjunction with the house volume to predict the average ventilation effectiveness in the suites. Due to the possibility of interzonal flow, within a suite, the Halitec sensors were located in the kitchen, living room, bathroom and bedroom. Because of differences between the actual house volume and the effective house volume, results of this test provide a lower bound on the ventilation effectiveness. The methodology employed in this test is developed in Moffatt et al[11]. [CMHC, Investigation of HVAC in Current Mid- and High-Rise Residential Buildings 1997].

Air leakage Characterization of the Suite

The air leakage in the suite was characterized using a blower door test. An *approximate* effective leakage area (ELA) for the EH and conventional suites was obtained for the suites using a modified CGSB-149.10-M86 test procedure. The ELA obtained was approximate because it was not possible to control the pressure at all bounding surfaces to the suites. In particular, the pressures in the suites located above the test suites were not controlled, nor was the pressure in the crawl space. Due to these circumstances, the ELA should be considered an approximation only.

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[11] Investigation of HVAC in Current Mid- and High-Rise Residential Buildings, , Canada Mortgage and Housing Corporation, Ottawa, Ont., Canada, 1997.

The air leakage in the test suites were further characterized using a smoke pencil in conjunction with the blower door in order to locate leakage sources in the suites.

Chapter 4: Results of Air Quality Testing

Results of the IAQ analysis are presented in this chapter. The results of the testing in the EH and conventional suites are compared with each other, and where appropriate, with established guidelines[12,13,14]. It must be stressed that the established guidelines have limited meaning in the context of an environmentally hypersensitive occupant, as the guidelines are established for an "average" individual. The guidelines are presented here merely as a bench mark.

Ventilation effectiveness

The ventilation effectiveness of the EH unit and the conventional suite were measured using a doping test. Refrigerant R232A was injected into the suites and the concentration decay was monitored using a Halitec data-logger with 4 channels. Because of the potential for inter-zone flow within the suite, the 4 sensors were located in the living room, bedroom, kitchen and bathroom, corresponding to Channel A, Channel B, Channel C and Channel E, respectively. By observing the decay curve, the time constant for air exchange may be predicted for the suites. The concentration decay curves are presented in Figure 1 and Figure 2 below. The decay curves exhibit a well behaved exponential curve, as expected.

[12] ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality. American Society of Heating, Refrigeration and Air Conditioning Engineers, 1989.
[13] Environmental Health Directorate, Exposure Guidelines for Residential Indoor Air Quality, Dept. of National Health and Welfare, Ottawa, Ont., 1989.
[14] Environmental Health Directorate, Fungal Contamination in Public Buildings: A Guide to Recognition and Management, Dept. of National Health and Welfare, Ottawa, Ont., 1989.

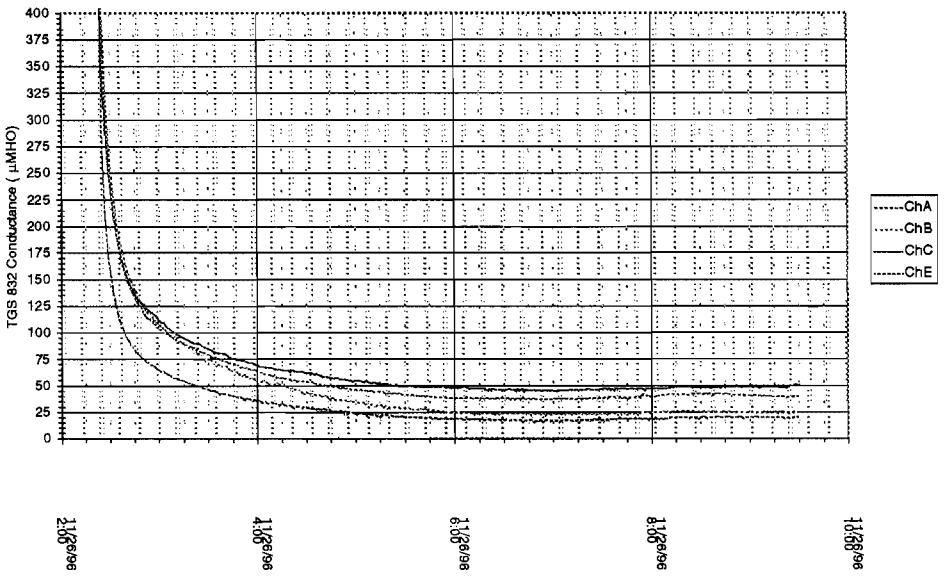

Figure 1: Tracer Gas Decay Curve for EH Suite

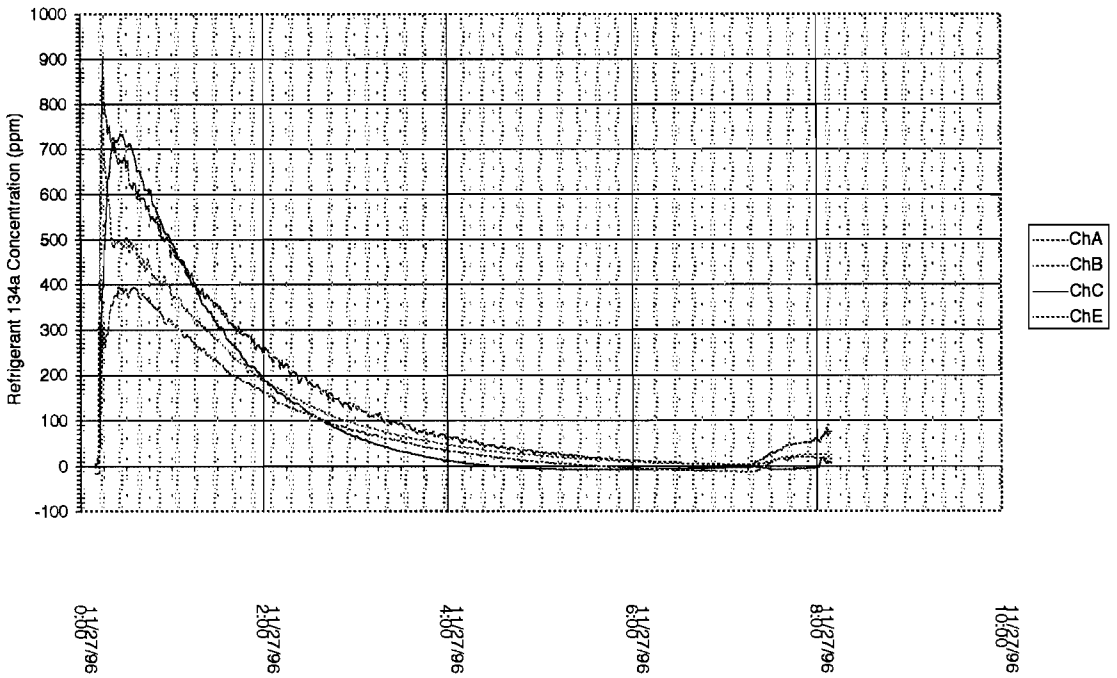

Figure 2: Tracer Gas Decay Curve for Conventional Suite

Based on this data, the air change rates are summarized in Table 2. The calculated air change rates are apparent air change rates because:

- Air change in a room may be due to interzonal flow and from outside the suite. The contribution from each source is not known
- The effective volume of the room is an estimate based on the dimensions, and does not account for the volume of furnishings, appliances and dead air spaces.

Testing was performed in the suites under normal operating conditions. In the EH Suite, the HRV was operating at mid range, with all interior doors open, and windows and exterior doors closed. In the Conventional Suite, the interior doors were open, and the windows and exterior doors were closed.

Table 2: Apparent Air Change Rate in Test Suites

Location	**Air Change Rate [Air Changes per Hour], *(litres/sec)***			
	Living Room	Bedroom	Kitchen	Bathroom
EH Unit	[2.05], *(25.6)*	[1.63], *(11.6)*	[2.19], *(14.2)*	[1.86] *(15.7)*
Conventional Unit	[0.89] *(9.25)*	[0.64], *(5.17)*	[0.63], *(5.64)*	[0.73], *(1.59)*
Air Quality Standards and Guidelines				
ASHRAE Standard 62-1989 Target guideline			0.35 ACH (or not less than 7.5 L/sec/person)	

The italicized numbers are estimates of the air change rate in litres per second. These estimates are based on the volume of each room, rather than an effective volume. Therefore, these values should be considered a minimum air change rate as the effective volume will be less than the actual volume.

Ventilation Fans Flow Rates

The ventilation fans were characterized for flow rates using ASHRAE standard 62 Appendix. Table 3 summarizes the flow rates for the different fans operating separately and together for the EH unit and the conventional suite

Table 3: Exhaust Fan Flow Fates for Test Suites

Suite	Fan Location	ASHRAE 62 Requirements	Flow Rate [L/sec]
EH Unit	Bathroom	25	25
	Dryer		33.5
	Oven		54.8
	Stove	50	55.5
	All fans Operating		138.2
Conventional Suite	Bathroom	25	39.8
	Kitchen	50	39.6
	All Fans Operating		59.8

HRV

The flow rate of the HRV was not measured directly by Sheltair staff, as it would have entailed partial disassembly of the unit. However, the unit was tested during balancing, and the following flow rates were recorded at high speed:

Table 4: Flow Rate in HRV

HRV Flow	Flow Rate [L/sec]
Supply Side	42.5
Exhaust Side	40.1

Effective Leakage area

A depressurization test using a blower door fan was conducted in the EH unit and conventional suite in order to obtain estimates of the effective leakage areas (ELA) and normalized Leakage Areas (NLA)[15] for the suites. This test was only approximate, because it was not possible to control the pressures across all the surfaces of the suites. The suites above the EH unit and the conventional suite were not controlled for pressure, nor was the crawl space below the test units. However, when testing the EH unit, the corridor and conventional test suite were exposed to ambient conditions. Similarly, when the conventional suite was tested, the EH unit and the corridor were at ambient conditions. Because the ceilings and floors of the test suites may have been exposed to pressure regimes

[15] The normalized Leakage area (NLA) is the ELA divided by the suite envelope area. The envelope area includes perimeter wall (including doors and windows), ceiling and floor areas

different from ambient conditions, the measured ELA results are not an absolute measure of effective leakage areas. The results of the blower depresurization test are presented in Table 5.

Table 5: Effective Leakage Areas (ELAs) of Test Suites

Suite	ELA [cm^2 @ 10 Pa.]	NLA [cm^2/m^2 @10 Pa.]	ACH @ 50 Pa.
EH Unit, HRV unsealed	306	1.48	5.75
EH Unit, HRV sealed	261	1.26	5.20
Conventional Unit	462	2.23	10.6

A further set of pressure measurements were recorded to establish the pressure differences among the EH suite, the conventional suite and the corridor under normal operating conditions. Table 6 summarized the results of this test.

Table 6: Inter-zone Pressure Differences

Measurement	Pressure difference [Pa]
EH Suite to Outdoors with HRV operating	1.5
EH suite to corridor	-5 to -7
EH suite to conventional suite	-2 Pa

The results above suggest the EH suite is somewhat pressurized relative to outdoors. However, the EH suite is depressurized relative to the adjacent (conventional) suite and to the corridor. This implies that if there is communication (i.e. a leakage path) between the EH Suite and adjacent spaces, the flow will be into the EH Suite. This is potentially problematic. Anecdotally, the occupant of the EH suite can smell smoke in her suite when she is in the laundry room.

Smoke Pencil Test in the EH Unit

The ELAs recorded in the previous section are somewhat larger than expected. In order to characterize the sources of leakage in the EH unit, the suite was depressurized to 30 Pascals using a blower door, and a smoke pencil was used to locate leaks. In general, the major leaks were found around the outlets for electricity switches, telephone hook-ups and television receptacles. Leaks were detected around the face plates on all the walls, including intra-suite, inter suite and exterior walls. Also, the fuse box was a large area exhibiting vigorous flow. Most of the cutouts for plumbing were caulked and exhibited no significant

leakage. However, there were 2 notable exceptions. The drain pipe for the washing machine and the pipe for the shower head were not caulked, and exhibited vigorous leakage.

Other significant leakage areas were the pocket doors separating the bathroom, laundry room and kitchen areas. Leakage through these large openings was vigorous. Finally, the drain holes in the bottom of the window frames exhibited vigorous flows. The entrance door to the EH unit was not tested, as the blower door was installed in that door. Therefore, it is not known how significant the entry door is to the total air change rate in the suite.

Temperature, Relative Humidity, Carbon Dioxide, Carbon Monoxide

Temperature, relative humidity, carbon dioxide and carbon monoxide were logged twice in the EH unit and once in the conventional unit. Because only one sensor was available, concurrent testing of the EH unit, the conventional suite and outdoors was not possible during the November site visit. Instead, the monitor was located in the EH unit and the conventional suite for 24 hour periods, and located outdoors for a short test period in between testing the EH and conventional units.

Temperature and Relative Humidity

Plots for temperature, relative humidity, carbon dioxide, and carbon monoxide are presented for the EH and conventional suites. The temperature and relative humidity profiles were constant over the testing period, and exhibited no unusual characteristics. The relative humidity in the EH unit remained at approximately 27% and 43% for November and June, respectively, and at 30% in the conventional suite. These relative humilities are within Health Canada guidelines of 30 – 80 % in summer and 30 – 55% in winter. The temperature in the EH unit was relatively constant at approximately 25 and 23 degrees Celsius for sampling in November and June respectively, and in the conventional suite, it was approximately 23 degrees Celsius

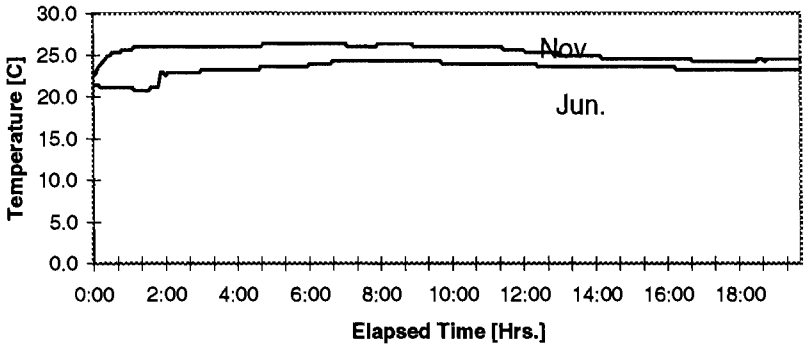

Figure 3: Temperature Profile in EH Suite

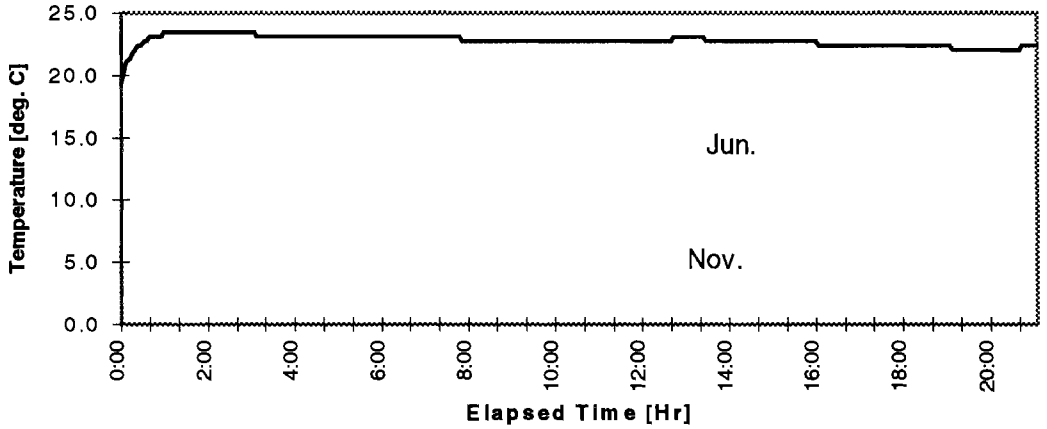

Figure 4: Temperature Profile in Conventional Suite

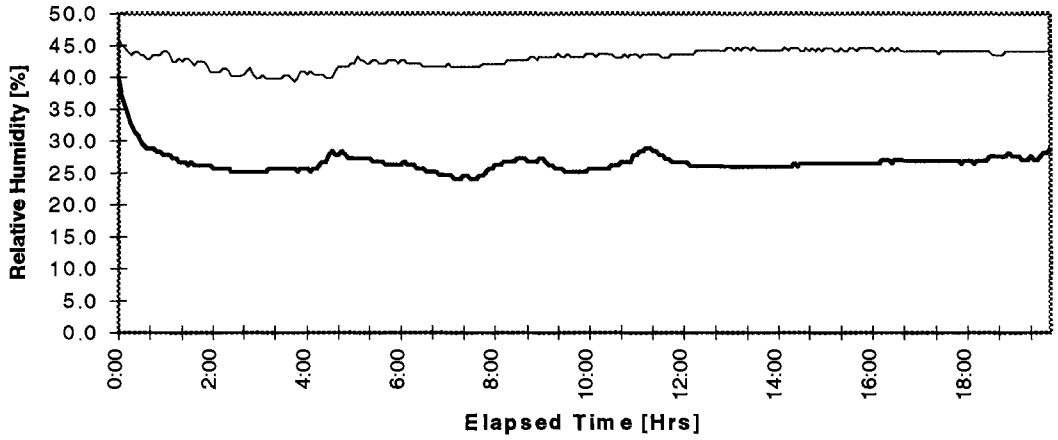

Figure 5: Relative Humidity in EH Suite

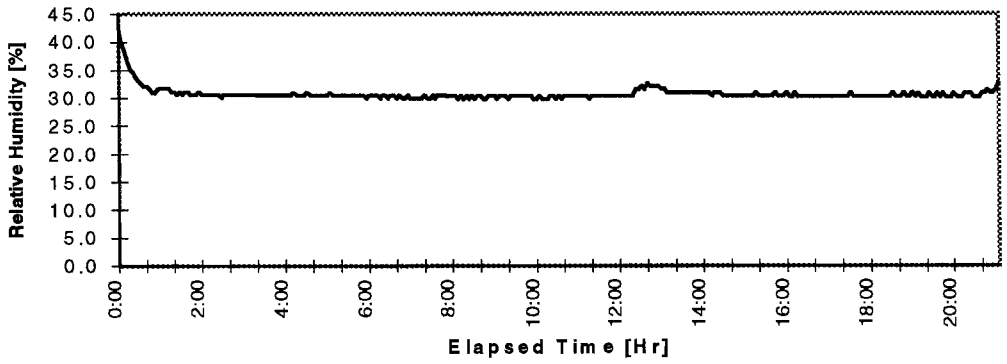

Figure 6: Relative Humidity in Conventional Suite

Carbon Dioxide

The carbon dioxide levels in both suites varied widely from outdoor ambient levels of approximately 400 ppm when the suites were vacant up to levels of 800 ppm when people were in the suites performing the IAQ testing. The CO_2 levels remained well within the guidelines for acceptable indoor concentrations as shown in Figure 7, Figure 8 and Table 7.

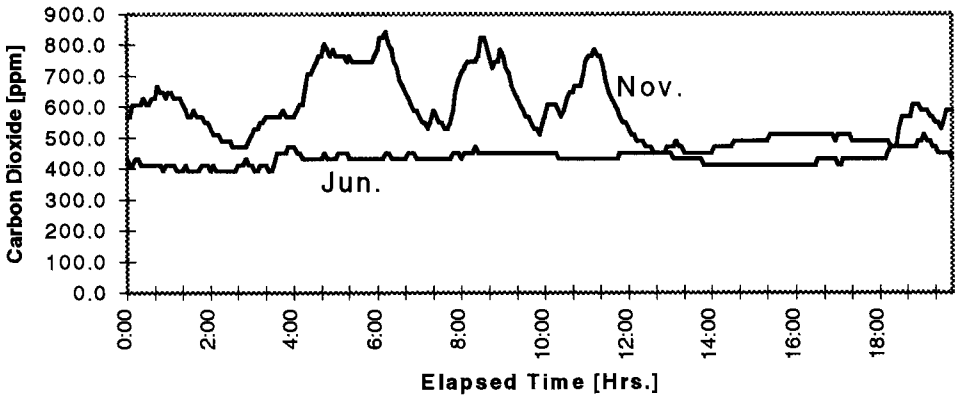

Figure 7: Carbon Dioxide in EH Suite

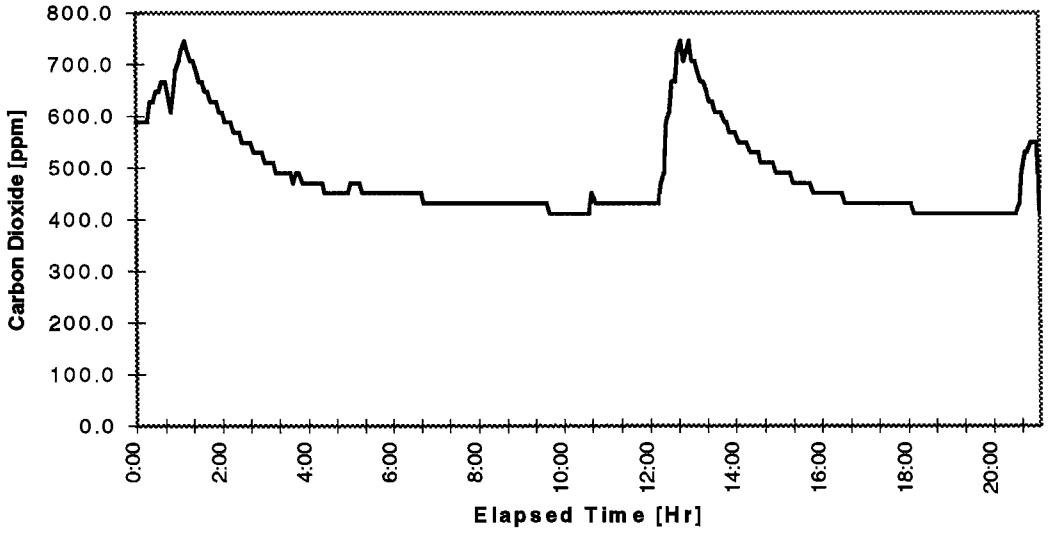

Figure 8: Carbon Dioxide in Conventional Suite

Table 7: Carbon Dioxide Levels in Test Suites

Measured Concentrations	Concentration [ppm]
EH Unit Range	400-800
Conventional Suite Range	400-750
Measured Ambient Outdoor Level	400-450
Air Quality Standards and Guidelines	
Typical Indoor Air Concentration	450-5600
Health and Welfare Canada Acceptable long term exposure range	3500
ASHRAE 62 - 89	1000

Carbon Monoxide

The CO level remained at a relatively constant level of about 0 ppm in the EH unit during testing in November and June. During the November testing, when the monitor was placed outside the apartment, the CO level jumped to a level in excess of 50 ppm. The exact CO concentration was not known, as the range of the CO monitor is 0 to 50 ppm. When placed in the conventional suite, the CO level dropped down to approximately 0 ppm for 4 hours and then increased to over 50 ppm for in excess of half an hour. The CO then decayed to a level of approximately 25 ppm, and then exponentially increased to a level of 50 ppm, at which point the monitor was shut off.

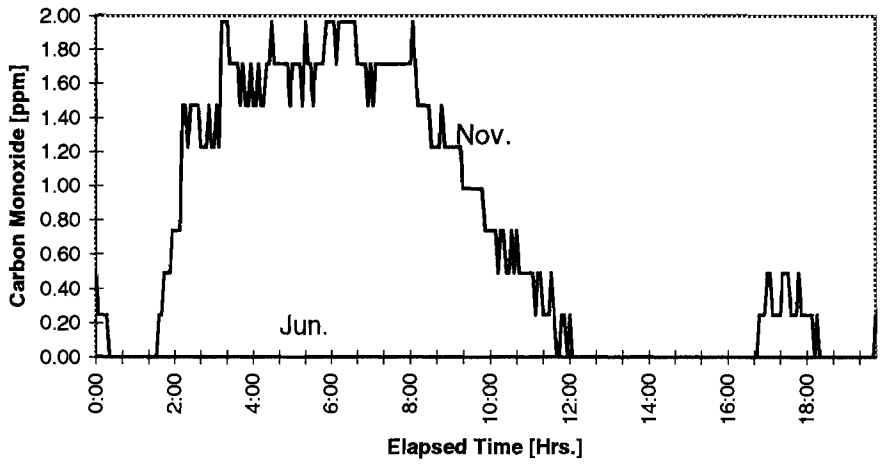

Figure 9: Carbon Monoxide in EH Suite

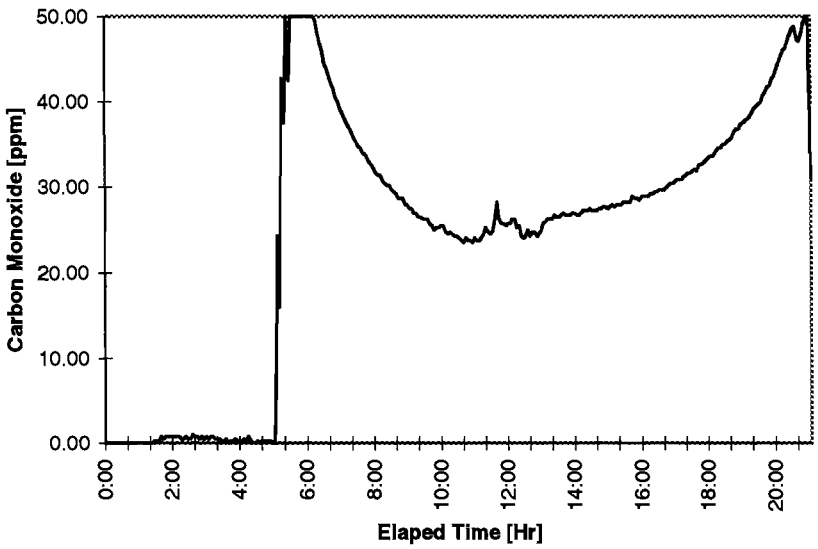

Figure 10: Carbon Monoxide in Conventional Suite

As a basis for comparison, Table 8 summarizes indoor air quality standards for carbon monoxide.

Table 8: Carbon Monoxide in Test Suites

Measured Concentrations	Concentration [ppm]
EH Unit Range	0-2
Conventional Suite Range	0-50
Measured Ambient Outdoor Level	50
Air Quality Standards and Guidelines	
Typical Indoor Air Concentration	1-87
Health Canada Acceptable short term exposure range	25
Health Canada Acceptable long term exposure range	11
ASHRAE Standard 62-1989 Target guideline	9

It is not clear from the testing performed whether the measured CO was an isolated event, or whether there is a chronic, intermittent problem in the apartments. Further, it is not clear whether the high CO levels are restricted to the conventional suite, or whether the EH unit or even the entire apartment may be exposed to elevated levels of CO. The high measured value of CO in the outdoor sample is also surprising and it is not known if it was temporary.

As the levels of CO exceed the standards published by Health and Welfare Canada, the building manager was informed there may be a problem, and is monitoring the CO level in the apartment. To date, there have not been any subsequent reports of the elevated CO concentration.

VOC levels

The VOCs for the EH suite was measured once before occupancy in November, and twice after occupancy in March and again in June. Similarly, VOCs were measured in the conventional suite on two separate occasions; once in November and again in March. The samples were analyzed for total VOC concentration and the 12 most common VOC's. Table 9 summarizes the results of the VOC testing. Note the concentration of TVOC increased sharply in June. This corresponds to installation of carpets in the commercial portion of the building, located approximately 40meters from the EH suite.

Table 9: TVOC Concentrations[16]

Location	TVOC Concentration [mg/m^3]		
	November	March	June
EH suite	1.22	0.02	3.5
Conventional Suite	0.926	3.0	

Although there are no Canadian or US standards for TVOC, target and action levels of 1 and 5 mg/m^3 are being discussed. The European Union has prepared a target guideline for TVOC of 0.3 mg/m^3, where no individual VOC should exceed 10% of the TVOC concentration[17].

The top VOC identified were similar in the EH and conventional suites and are summarized below. Due to the nature of the test, it was not possible to obtain absolute concentration of component VOCs. Further, testing of outdoor conditions for VOCs was not conducted, therefore, it is impossible to assess the source of the VOCs.

$C_6 H_6 O$ - Phenol
$C_{13} H_{28} O$
$C_{13} H_{28} O$, 1 - tridecanol
$C24 H_{24}$ - 4, 5 - dimethyl nonane

[16] The method used to measure the VOC's in this study gives results which are lower than those obtained using a passive VOC sampler or Tenax tube {[Ref 10]. These absolute values, therefore cannot be comparedwith European Union guidelines. The TVOC values in the EH and conventional suites, however, can be compared to each other.

[17] Federal - Provincial Advisory Committee on Environmental and Occupational Health, Indoor Air Quality in Office Buildings: A technical Guide, Health Canada, Ottawa, Ont., 1995

C12 H_{26} - 5 - methly undecane
C12 H_{26} - n - dodecane
C_{14} H_{22} O, 2, 6 - bis(1, 1 - dimethyl)cyclodiene -1, 4 - dione
C_{15} H_{22} O - vetivone
C_{16} H_{26} O, 2,6, - bis(1, 1 - dimethyl) -4 - ethyl

It appears that the TVOC concentration in the EH suite is slightly higher than that of the conventional suite in November, but much lower in March. The significance of these numbers is difficult to assess, and many more measurements would have to be taken to determine the reproducibility and accuracy of the results.

Formaldehyde

Formaldehyde concentration was measured once before and twice after occupancy in the EH Suite. In the conventional suite, formaldehyde concentration was measured only once. Results of the test are summarized in Table 10.

Table 10: Formaldehyde Concentration in Test Suites

Location	Formaldehyde Concentration [ppm]		
	November	March	June
EH suite	0.013	0.013	0.008
Conventional Suite	0.044		
Air Quality Standards and Guidelines			
Health and Welfare Canada Target Level		0.05	
Health and Welfare Canada Action Level		0.10	

Mold

Results of mold testing for samples obtained in November showed very low or no fungal colony forming units (CFUs) in the EH suite. The only mold recovered in the EH suite was Alternaria alternata which is a common leaf decay fungus, and is not uncommon in indoor air. In the conventional suite, the RCS strips detected moderate CFUs in the bathroom. The variety of organisms detected in the sample (e.g. Colletotrichum gloeosporioides, yeasts, bacteria) are typical of moist environments. The unusually low levels of mold outside during the November sampling may have been due to the wet weather conditions prior to and during the sampling. During the sampling in November, the

conventional suite had been occupied for approximately 2 months, while the EH suite had not been occupied. Mold testing of the EH suite after 4 months of being occupied showed the presence of molds in the bathroom, living room and kitchen. However, the levels were low and the species were mixed and were of the outdoor types.

Table 11: Mold CFUs in Test Suites

Location	Mold Concentration [CFU/m^3]		Species
	November	June	
EH Suite, Bedroom	0	0	
EH Suite Bathroom	0	13	Alternaria alternata
EH Suite, Living room/Kitchen	6	38	Alternaria alternata, Cladosporium
Conventional Suite, Living room/Kitchen	0		
Conventional Suite, Bathroom	75		Ulocladium consortiale, Colleiotrichum gloeosporioides, Volutella ciliata, Malbranchea sclerotica, yeasts (Sporobolomyces sp., Cryptococcus sp.), Bacteria
Outside	13	138	Penicillium aurantiogriseum
Air Quality Standards and Guidelines			
Health Canada exposure range	150 CFU/m^3 of mixed species 50 CFU/m^3 of a single species		

Dust

Dust levels were monitored continuously for the EH unit and the conventional suite in November and again for the EH suite in June. Graphs of dust concentration over time are plotted below. The dust monitor logged PM 0.5[18], PM 1, PM 2, PM 3.5, PM 5, PM 7.5, PM 10 and PM 15. Upon examination of the charts, the concentration of dust decreases with particle size. This is to be expected, as the larger particles fall faster than the smaller particles.

November testing revealed episodes of dust concentration in excess of 150 ug/m^3 were observed in the EH unit. Anecdotally, while performing the air

[18] PM 1 corresponds to Particulate Matter of 1 micron size.

testing in the suite, a visible film of dust was noticed on a number of horizontal surfaces. Upon discussion with the designer, it appears that touch-ups to the drywall were completed after the last cleaning of the suite, and this might explain the elevated levels of dust.

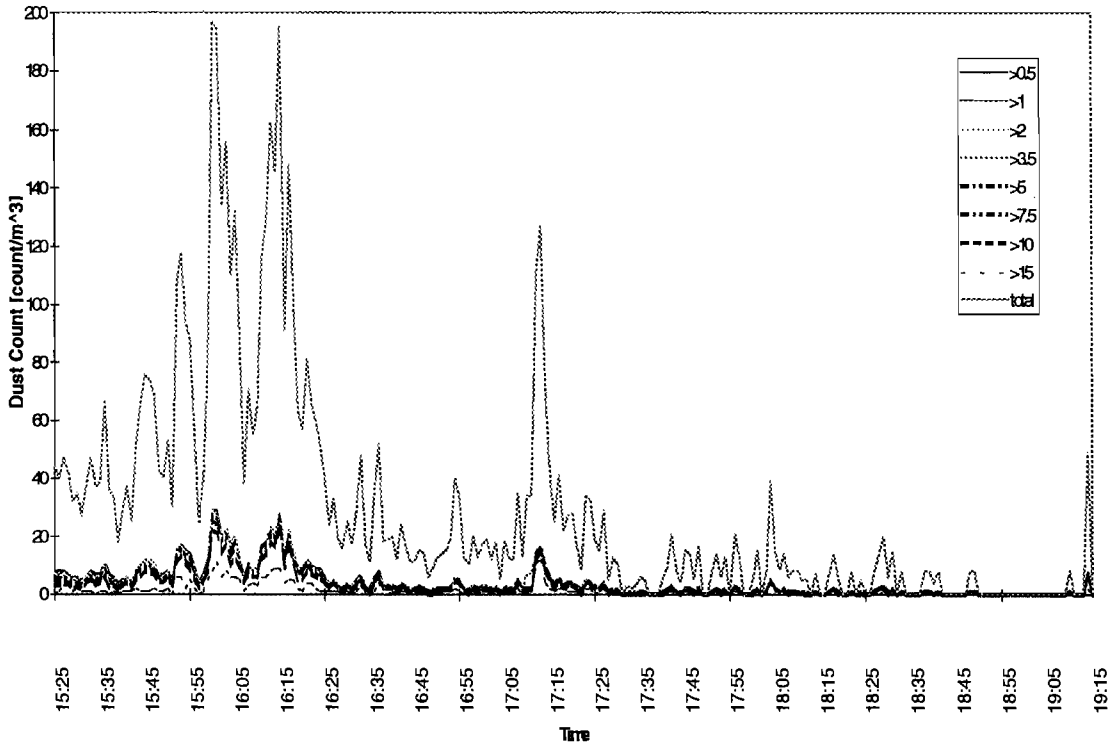

Figure 11: Dust Concentration in Test Suites

Table 12: Dust Concentration in Test Suites

Measured Concentrations	Concentration [ug/m^3]	
	November	**June**
EH Unit, occupied, average	50.3	0.0
EH Unit unoccupied, average	1.2	0.0
Conventional Suite, occupied, average	59.4	
Conventional Suite, unoccupied, average	0	
Air Quality Standards and Guidelines		
Health Canada Acceptable short term exposure range	100	
Health Canada Acceptable long term exposure range	40	
ASHRAE Standard 62-1989 Target guideline	50	

Summary of IAQ Test Results.

Table 13 summarizes and compares the IAQ parameters tested in the EH and Conventional Suites. Temperature, relative humidity, carbon dioxide, and dust concentrations are similar in the two suites. Carbon monoxide was found to be higher in the conventional suite during testing in November. No conclusions can be made from the TVOC measurements. Additional tests are needed to determine the TVOC concentrations with more accuracy, and to identify the sources. The three sets of measurements for formaldehyde in the EH suite showed consistently lower levels than in the conventional suite. Mold counts appeared to be lower in the EH suite, however, both suites had low mold counts indicating that mold was not a problem during the time of testing. The EH suite was found to have a lower effective leakage area than the conventional suite implying it was built tighter. Finally, the ventilation rate of the EH suite was three times higher than that of the conventional suite.

Table 13: Summary Statistics

Parameter	EH Suite			Conventional Suite		
	Nov. (Unoccupied)	Mar.	Jun.	Nov.	Mar.	June.
Average Temperature[[deg. C.]	25.40	23.4	23.5	22.8		
Relative Humidity [%]	26.61%		43%	30.7%		
Carbon Dioxide [ppm]	567		450	487		
Carbon Monoxide [[ppm]	0.7		0	24.7		
VOC [mg/m^3]	1.22	0.02	3.5	0.926	3.0	
Formaldehyde [ppm]	0.013	0.013	0.008	0.044		
Mold [CFU]	0		25	75		
Dust [ug/ m^3]	50.3		0	59.4		
Ventilation Rate [Litres/sec.]	16.8			5.41		

Chapter 5: Interviews

A series of interviews were conducted to improve the understanding of the project. Interviews were conducted with:

- David Rousseau, the consultant hired by the project architect to provide design guidance for the EH suite
- The occupant of the EH suite, and
- Janice Webster of the Capitol Region Housing District who manages the apartment block

In selecting a tenant for the EH suite, the CRD requested the assistance of the Canada Mortgage and Housing Corporation. Based on the Experience with the tenants at the Barrhaven Multi Unit Housing Project in Nepean Ontario, a set of criteria was developed and forwarded to the CRD (Appendix 3).

Interview with David Rousseau

Mr. Rousseau was quite positive about the results of the project. He was hopeful that more units would be built, and thought that the occupant's living conditions had improved over her previous situation. However, Mr. Rousseau voiced a number of concerns about the project.

Mr. Rousseau thought the project was not adequately supervised, and he was not certain whether the architectural details specified for the EH suite were followed. For example, the site architect had little experience in site supervision, and did not know what to look for in terms of deficiencies. Further, the construction superintendent did not have experience with building an EH suite and there was some question of the contractor's commitment to the project.

Mr. Rousseau thought the Capital Region Housing District's (CRD) management approach to this project could have been improved in:

- design choices
- site supervision, and
- operations management.

Mr. Rousseau suggested there was an opportunity for the CRD to modify their management style to deal with the EH Suite and its occupant. The analogy of someone in a wheelchair was expressed. Buildings are now designed, built and operated to be accessible by wheelchairs. The management of buildings have evolved to accommodate these changes. While the EH suite is specifically designed for an individual with special needs, the CRD has not been proactive in evolving its management style to accommodate the individual needs of the

occupant of the EH suite. The CRD appears to consider the EH suite to be the same as all the other suites in the complex, but constructed with some special features. There was a lack of recognition that choices made for pest management in landscaping, carpet cleaners in the common areas of the apartment or exhaust from the common laundry facilities have a direct and negative impact on the occupant of the EH suite. The main reason for this management style appears to be that the activities and responsibilities of the CRD are bounded by the Tenant Landlord Act of BC, and that Act is meant to protect an *average* occupant. There was also some speculation that the CRD is ruled by precedent, and it would be dangerous for the CRD to treat the EH suite on an individual basis as this might imply additional responsibilities to other occupants with special needs.
When asked what he might do differently next time, Mr. Rousseau expressed the following thoughts:

- improve the field supervision to ensure that the suite conforms to the design details specified;
- set specifications for the air-tightness of the suite, and perform testing to verify the specification is met;
- take half a day at the beginning of the project to meet with the contractor, site supervisor, and project management staff to walk through the design of the suite in order to discuss the design.

Interview with the occupant of the EH Suite

To obtain information on the suitability of the EH suite to the occupant's needs, she was asked to fill out a questionnaire. A transcription of her response to the questionnaire is provided in Appendix 2.

The occupant was grateful to be given the opportunity to live in the EH suite, and overall she was pleased with her new home. However, she felt there were some problems with the suite and its management. As a result of these problems, she expressed the feeling that the current configuration of an EH suite within a multi-family apartment block situated on a site that will have construction occurring for the next 5 to 10 years had disadvantages that might not be amenable to resolution. In terms of specific problems with the suite:

- There is still a smell of "newness" about the suite. This suggests there may still be some off-gassing of volatiles from the building materials in the suite. The occupant noted that her glands continually hurt and that she feels better when she is outside than when she is in the suite.

- The occupant was aware of cigarette smoke in the utility room of her apartment, suggesting the suite was not as air tight as it should be. In order

to deal with this problem, the occupant taped shut the pocket door separating the utility room and bathroom, as she felt this was a large source of leakage.

- The presence of the laundry room within 5 meters of her front door and crawl space air vents below the windows of the EH suite means that the occupant is exposed to the smell of laundry detergent, perfumes and other fumes. In order to deal with this problem, she must tape her front door shut every night in order to keep out chemical irritants released in the vicinity of the EH suite.

- During summer months, the temperature in the suite was uncomfortable due to the absence of an air conditioner, and the presence of the HRV. Upon discussion of this problem with the CRD, a summer core was installed in the HRV[19].

In terms of problems with the management structure, the occupant expressed frustration in dealing with the CRD. She noted the CRD had not given written confirmation of their responsibilities to maintain the suite, and this was causing her some concern, especially with respect to changing the filters in the air scrubber. Further, the designer of the suite had developed a set of maintenance guidelines for the suite. The occupant had repeatedly asked to get a copy of the guidelines, but she was refused by the CRD.

During the spring of 1997, there were a number of occasions when building maintenance created conflicts with the occupant's needs. Painting in the corridor, pesticide spraying in the common area and installation of carpets in the commercial space are three examples where conflicts arose. She was given written notice of the first 2 activities. The occupant responded to the notification of painting by requesting that low emissions paints be used. The CRD responded to the request by providing her with alternative accommodation.

The occupant acknowledged the CRD was not fully informed of her special needs. However, Ms. Sawyer was trying to develop a positive working relationship with the CRD in order to help them operate in a more proactive fashion.

Interview with Janice Webster of the Capitol Region Housing District

Ms. Webster stressed that the design and construction of the EH Suite involved a trade-off between cost effectiveness while providing a clean environment for the occupant. Although Ms. Webster implied the project was not perfect, her feeling of the suite was that it had been quite successful, and she was happy with the

[19] A summer core is a baffle for the HRV that may be inserted to prevent heat transfer between supply and exhaust air. In this way, the HRV will not pre-heat air coming into the suite.

results. Ms. Webster stressed the EH suite is an ordinary suite constructed of special materials, and the contract and responsibilities of the CRD to the occupant of the EH suite are no different to the arrangements made with other clients.

In terms of lessons learned from this project, Ms Webster felt that there was insufficient time dedicated to the process of managing the project. Further there was a lack of continuity in management personnel and this created some problems. Finally, Ms. Webster thought there should have been an overall project manager involved from project conception to getting the occupant settled.

Conclusions and Recommendations

EH Suite Design and Construction

There was considerable effort made in designing the EH suite, and for the most part, the suite works well. Although improvements could be made in the design of the EH suite, the most significant improvements in design could be in how the suite might be incorporated into the design of the site and the apartment block in order to promote integration of the occupant without compromising the occupant's health.

If future EH suites are to be built within a larger multi family complex, it is recommended the location of the suite be chosen to minimize entry of irritants into the EH suite. Therefore, it is recommended to avoid locating EH suites in the vicinity of laundry rooms, adjacent to court yards or corridors frequented by smokers, or close to parkades and garbage facilities.

Future EH suites should be located on sites that are not likely to contribute to the condition of the occupant. Therefore, it is recommended to avoid locating EH suites on former industrial sites or adjacent to long term construction sites.

The same care and attention to detail that was used to design an EH Suite needs to be carried through to the construction of the suite. While air tight drywall and an air barrier were specified for the EH suite, the fact that the occupant could smell smoke suggests the suite was not adequately isolated from the rest of the building. Air testing of the suite verified the concerns of the occupant about the air tightness of the suite. It was found that the suite had an overall air change rate of 5.2 ACH[20] at 50 Pa. Therefore, it is recommended that specific performance targets be set for future EH units with respect to air tightness, and that the suites be tested during construction.

The EH suite was operated at a negative pressure relative to the rest of the building. This implies that if there are leakage paths between the EH suite and the rest of the building, contaminants will tend to flow from the rest of the building into the EH suite. Therefore, it is recommended that in future designs, the EH suite be designed and operated in order to maintain a positive pressure relative to the rest of the building.

Construction of the suite was finished late in 1996. Though considerable effort was made to seal exposed surfaces and use low emission building materials, the

[20] This value includes envelope leakage, inter suite leakage and leakage to the corridor.

occupant of the suite still notes the suite smells "new" after 8 months. This suggests that future works examine:

- Identification of materials that are posing a problem to the occupant, and minimizing its use in the future;
- the possibility of using more inert , low odour materials to construct the suite;
- improvements to the efficacy of the flush out period;
- selecting a clean location for the fresh air intake;
- development of guidelines to assist the occupant maintain the suite; and
- development of guidelines to assist management or owners maintain the suite and the building.

Indoor Air Quality of EH Suite

VOCs, formaldehyde, mold, dust and air change effectiveness were measured and compared between the environmentally hypersensitive suite and a conventional suite in the same building. Formaldehyde and mold were found to be lower, while the ventilation rate was higher in the EH suite than in the conventional suite

The EH suite at the Selkirk Apartments provides the occupant with an indoor air quality that is incrementally better than her previous accommodation. While the situation is by no means perfect for the occupant, she is coping better with her condition. If one uses the criteria of incremental improvements in order to assess the success of the EH suite, one may conclude that it is successful.

Interviews

Based on interviews with the tenant of the EH Suite, the suite designer and the property manager, it became evident that the management structure of a facility which contains an EH Suite must evolve. In particular it must be recognized that management can adversely impact the performance of the EH Suite through choices they make. At a general level, this implies that the Provincial Landlord Tenant Act may not provide adequate protection for a person suffering from Environmental Hypersensitivity. In the case of the CRD, it implies the need for the management to acknowledge the boundaries of the EH suite extend beyond the physical boundaries of the EH Suite, and includes the area that is likely to affect the health of the occupant of the EH suite. It is recommended that if more EH units are to be developed by public agencies, the management of those EH units be adjusted to reflect the special needs of the occupants.

Comments from Canada Mortgage and Housing Corporation

The first social housing project in Canada for people with environmental hypersensitivity, sponsored by the Barrhaven United Church and the Ministry of Housing of Ontario, also known as the Barrhaven Project, is a seven-unit apartment building dedicated for people with this condition. An evaluation of the project was conducted one year after occupancy. Though the evaluation did not include air quality measurements, the responses of the tenants indicated satisfaction with the units. Overall, this project was successful.

The special unit in a newly constructed apartment building in Victoria is an attempt to modify one unit in a conventionally constructed apartment building into an accommodation suitable for a hypersensitive individual. Is it possible to create a living space with clean air within the confines of a typical apartment building?

This study by Sheltair combined an assessment of the indoor air quality and ventilation characteristics of the special unit with an evaluation of the occupant's level of satisfaction with the unit. Tests for leakage, ventilation rate and other indoor air parameters were carried out.

The results showed that the special unit was less leaky compared to a conventional unit in the same building. However, the air tightness could still be improved to prevent infiltration of pollutants from the corridor and adjoining units.

Measurements of various indoor air parameters were useful. Temperature, relative humidity and carbon dioxide were very similar in both units. There was an indication of a carbon monoxide problem in the conventional unit which was non-existent in the special unit. Formaldehyde was found to be lower in the special unit before it was occupied and after the tenant had moved in. In the conventional suite, formaldehyde is likely contributed by the occupant's furnishings as well as the particle board cabinets.

The few TVOC measurements proved to be inadequate to characterize the level of chemical contaminants. A larger number of measurements are needed to determine if there is a quantifiable difference between the EH and conventional units and to identify the sources of the volatile organic compounds in the EH unit.

The ventilation rate of the EH unit is much higher than that of the conventional unit. This was expected, since the EH unit has its own balanced ventilation system while the conventional unit gets outside air from the pressurized corridor. Because low-emission materials were chosen for the EH unit, one would expect lower TVOC. With a higher ventilation rate, one would expect further lowering in TVOC. From the few measurements taken, this does not appear to be the case, suggesting that there may be contributions to the TVOC other than what is generated inside.

Because the EH unit is depressurized relative to the corridor and the conventional unit, there is a possibility of pollutants coming from these areas. It is also possible that chemical gases from the asphalt roof subjected to the sun's heat could be pulled into the unit. Lastly, residual oils from the aluminum core of the heat recovery ventilator is a possible source of volatile organic compounds.(Footnote- Emission testing of a similar core by the National Research Council showed the presence of hydrocarbons.)

Neither the EH unit nor the conventional unit indicated the presence of molds. At the time of the testing, mold did not appear to be a problem in the two units in the new building. The true test for molds, however, would be at a much later time after prolonged occupancy.

The occupant reported slight improvement over her previous residence but reports some discomfort and 'new' smells. The latter is difficult to eliminate completely, owing to all the new materials. It will be useful to continue to monitor which particular materials are releasing new smells. Are the formaldehyde-free cabinet materials sealed sufficiently? What materials should be minimized or avoided? In the Barrhaven project, it was evident that when all other sources of pollutants were eliminated, even the odours of new solid woods were found to be a source of irritation. Either less wood should be used or all surfaces are thoroughly sealed.

It is interesting that the occupant, although she is positive about the unit, does not mention the benefits from not having emissions from carpets nor mold, the two predominant pollutants in houses. The impact of these pollutants are more obvious when people are experiencing the problems, i.e.when they are living in a carpeted or moldy place. In the EH unit, these pollutants are absent, and the attention is focused on other contaminants. This study as well as the Barrhaven study point to the need to exclude as completely as feasible the contaminants, and the degree to which the environment is tolerated will depend on the sensitivity of the individual.

The tenants of the Barrhaven housing can draw support from one another because of their similar needs. The lone tenant in a conventional building lacks this kind of support. Building a cluster of units for tenants with similar needs has advantages.

It is feasible to create 'clean air' apartments within conventional apartment buildings. However, there are challenges. The consultant's recommendations should be followed. These recommendations include proper siting of the units within the building to minimize pollutants from different sources; choosing a good location of the building; supervising construction to more effectively isolate the units from adjoining apartments; continuing to select materials that are inert or have low impact; ensuring that the fresh air intake brings in truly fresh air; and adopting building management practices that are supportive of the needs of the tenants. Many of these recommendations are good practices for constructing apartments. Adopting many of these practices would increase the availability of suitable rental units for people who for health reasons are in need of clean housing.

Virginia Salares
August 28, 1997

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Appendix 1 Drawings

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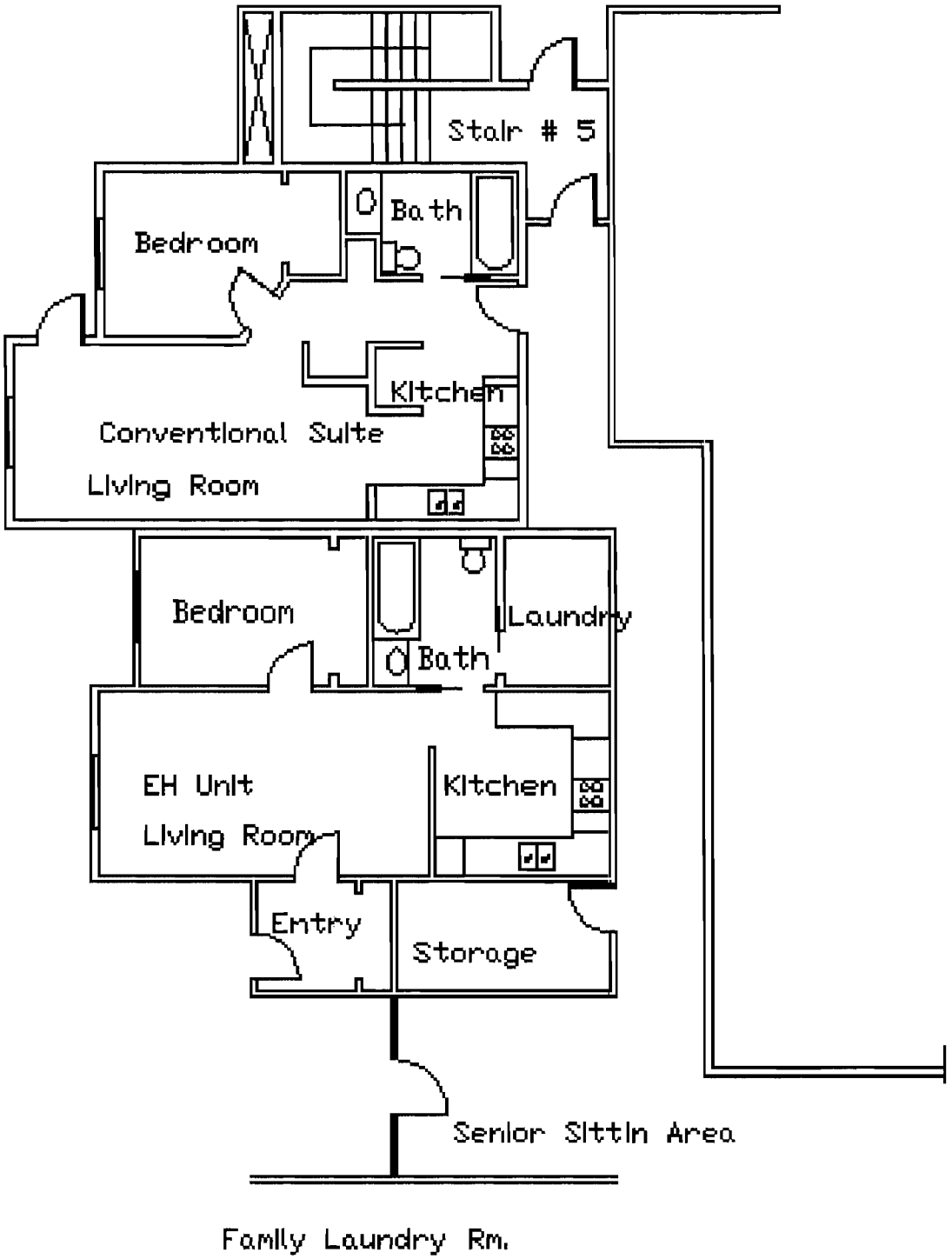

Appendix 2: Questionnaire response from EH Suite Occupant

Selkirk Environmental Unit Questionnaire

Personal Information

What are your major activities that create dust, odour or toxins?
Cooking, watching T.V, taking showers, paper work, boxed old computer,

How much time do you spend in the suite?
18 - 23 hours a day.

Which room do you spend the most time in?
Living room - I've created a living room for myself in it.

Are there any rooms you feel uncomfortable in? If so, please describe.

- *Entrance foyer - new smell, laundry smell*
- *Bathroom - cold*
- *Utility room - sometimes smell smoke*
- *So far, I'm not spending time in the bedroom where I set up a desk and old computer*

Sense of well being

Do you feel at home inside the suite?
Yes. At first I felt as if I were in a motel (ground floor, not much furniture, no carpet)

Do you feel comfortable as a resident of the apartment block?

- *So far, I don't feel part of the apartment block because it makes me feel sick and I don't know anyone. Also, I feel strange - "the woman with allergies"*
- *There is a blank beside #14 [the EH suite number] on the intercom panel.*

Do you feel better, worse or the same after spending time in the suite (relative to outdoors or your previous home)?
I feel worse in the suite than outdoors. Some of my symptoms are worse than in my previous home, but some are better and I no longer have "crisis days"

What do you like best about the suite?
Floors, ventilation/HRV, outside entrance, oven in wall, doors to shut off rooms, special materials, not been smoked in, washer and dryer

What do you not like about the suite?
Close to laundry, no dishwasher, no heat lamp, no water purification system, dust, new smell small bedroom, no garbeurator small utensil drawer, no towel rack near bathroom sink, noisy refrigerator and stove fan

What changes in the suite would you recommend?
Better dust filter, more storage space, linen closet, dishwasher, heat lamp, water purification system, larger bedroom, no mail slot in door, blinds or heavier curtains
I don't understand the large gaps under the doors
I would very much like the fire alarm turned off

Personal Health while in the suite

Please describe specific allergic reactions you have while in the suite.
- *I am on hydrocortisone which is likely stopping some symptoms*
- *My glands hurt all the time - used to hurt when I was exposed to chemicals*
- *Fatigue and brain fog*
- *Some Pain*
- *Insomnia*
- *I react to the heating system, but not as much as in November (I rarely use it).*

Please describe specific respiratory ailments while in the suite.
Sneezing, some congestion

Please Describe your symptoms:
Type
- *cough*
- *dizzy*
- *night sweat*
- *extremely fatigued*
- *muscle pain*
- *glands hurting*
- *crying in night*
- *feeling desperate*
- *often very depressed after too much physical activity or mental activity*
- *overwhelmed by illness and housing situation*
- *sneezing insomnia*
- *eyes swell*
- *headache*
- *sinus congestion*
- *gastrointestinal problems*

Severity

Afternoons are better

Duration
glands hurt almost constantly; insomnia for 1 - 4 hours

Frequency
- *Insomnia often*
- *Muscle pain varies, but usually every day*
- *Neck hurts frequently*

Can you identify possible sources of problems?
- *Still new feeling as if still toxic*
- *Kitchen appliances*

Are there additional stressors from the rest of the building that impact your health (noise, odour light, indoor temperature). If so, how significant are these stressors?
- *The fire alarm ringing in my suite is very difficult - it shatters my nervous system. Sometimes other noises.*
- *Smell of cigarette smoke in utility room in evenings - sometimes - (maybe comming from outside?)*
- *Laundry smells are a real problem.*

Air in the Suite
Do you feel you are getting enough fresh air in the unit with the windows closed?
I'm not sure; I miss a breeze

Does the air feel fresh to you?
Often it doesn't Sometimes it is adequate

Are there any odours in the suite? If so, please describe.
- *I think the appliances are giving off odours. Also my boxes*
- *I don't understand how to ventilate the oven*

Please take additional space to make other comments on your feelings about your suite
- *The construction outside is probably affecting me. I dread the day when they work closer to me - both the noise and dust will likely affect me.*
- *I wonder if I will ever be able to sit outside on my patio - laundry fumes, cigarette smoke*
- *I think the newness is a problem causing me flu-like symptoms*
- *I would like an intercom connection*

Appendix 3: Suggested Criteria for Selecting the Tenant for the EH Unit

1. Candidates must be able to present evidence from their physician of a need for clean housing. Applicants include those diagnosed with environmental hypersensitivity, chronic fatigue, asthma or other lung diseases.

2. The tenant will be selected from among candidates with moderate sensitivity, i.e. those who are not severely ill or debilitated. He/she should be capable of independent living and one who is not needing home care.

3. Only non-smokers should be considered.

4. The selection committee should visit the present residence of the most likely candidate to assess his/her coping skills as well as ability to maintain the unit. It is suggested that the selection committee also consult with people in the community who have known the candidate for some time.

5. The candidate should provide evidence of capability to discharge his/her responsibilities as a tenant (see list below).

The applicant(s) should be allowed to stay in the unit for at least 24 hours to test the tolerability of the unit.

Responsibilities of the Tenant

a. The tenant must agree not to bring a pet of any kind to the unit. The no pet rule will be strictly enforced in the lease.

b. The tenant shall agree not to use perfumed products, bleach, insecticides and deodorizers in the unit or allow others to smoke or bring polluting materials into the unit. The tenant's lifestyle should support objectives ofgood air quality.

c. The tenant should demonstrate willingness to look after the unit in a responsible manner. The tenant should recognize that overcrowding due to excessive amount of furnishings and stored materials will not support good indoor air quality. Moldy belongings should not be brought to the unit.

d. The tenant should be willing to have the unit inspected and maintained from time to time. The landlord must approve any maintenance activities by the tenant. The materials used should not degrade the air quality of the unit.

e. The tenant will maintain the mechanical system as required. The tenant's responsibilities include replacing filters and operating the system continuously. The ventilation system can be turned off only for short periods of time when the outside air is polluted.

What the Tenant Should Expect from Building Management

a. The building and the EH unit should be completed prior to occupancy. The unit must be thoroughly aired out to reduce offgassing from new materials before the unit is leased.

b. The building management should refrain from using pesticides inside or outside the building for any purpose. If there are indoor pests, the building maintenance will examine integrated pest management techniques for controlling pests.

c. Maintenance activities in the building should take into consideration the presence of a hypersensitive tenant in the building. These activities include painting, cleaning, caulking, lawn maintenance, etc. Low - VOC and low - odour materials should be used.

d. As many neighbouring units to the EH unit should be smoke-free. Adjacent units should also be advised to refrain from using strongly perfumed products, if these scents are infiltrating into the EH unit. If a problem occurs, the building management shall undertake to resolve the problem with the cooperation of the other tenants.

e. The building maintenance will make an effort to prevent vehicle exhausts originating from the garage from entering the building. This precaution should benefit not only the hypersensitive occupant but all other occupants of the building.

f. The building management shall endeavor to understand the needs of the hypersensitive tenant that relate to the occupancy of the unit in order to facilitate the resolution of problems that may arise.

Prepared by

Virginia Salares