Proposed Mixed-Method Study Design for the Assessment of Indoor Air Quality (IAQ) in Alberta Government Buildings for the Building Operators Management Association (BOMA)

by

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Abstract

The concepts of quantity and quality are implicitly implied in the term Indoor Air Quality (IAQ). The Building Environment Unit (BEU) of the Technical Services Branch of Alberta Infrastructure (AI) is a government group responsible for conducting IAQ Assessments in the Government of Alberta (GOA) owned and leased buildings. The BEU conducts IAQ assessments that are either reactive or proactive, with the first in response to an IAQ complaint and the latter as part of a regular inspection of the building's parameters.

In March 2011, the Building Operators Management Association contacted the BEU through another GOA department to undertake proactive verification of the air quality in selected GOA buildings as part of the BOMA BESt Initiative. Based on testing which occurred over approximately three (3) years in a wide variety of GOA buildings, as well as previous experiences and a review of recent IAQ literature, a cross-sectional, convergent-parallel, mixed-method study design for measuring both quantitative and qualitative information that may pertain to the perceived quality of the air inside GOA Buildings is proposed. The quantitative parameters proposed to be measured include: reviewing building documentation, inspecting the different components of the air handling unit(s), measuring Comfort Parameters, dust levels, airborne chemicals, supply and return airflow, and air pressurization in the occupied areas of the building. The qualitative measurements proposed to be observed include: interviewing the occupants of the building and asking them about their past and present perceptions and experiences concerning the building's IAQ.

Although the proposed BOMA IAQ Assessment method collects IAQ primarily on the day of the assessment, and is therefore prone to 'Healthy Worker Bias', the method is judged to be

comprehensive and it provides ways to limit errors that may be caused by selection bias and confounding factors. One of these methods includes selecting random and non-random air sample locations within the building.

Acknowledgement

The researcher would like to express their gratitude and appreciation to the management of the Technical Services Branch of Alberta Infrastructure for offering the necessary time and resources to conduct this research. The researcher is also very grateful to Professor/Supervisor Dr. Warren Kindzierski for his experience and guidance in shaping the project. In addition, the researcher would like to thank Dr. Megan Lefebvre and Dr. Robert Oster of the University of Alberta for offering their expertise and experience in qualitative study designs.

Table of Contents

Title Page i

Abstract ii

Acknowledgment iv

Table of Contents v

List of Tables xiv

List of Figures xv

List of Symbols xvi

1.0. Introduction and Objective 1

1.1 Introduction 1

1.1.1. Working Definition of Indoor Air Quality (IAQ) 2

1.1.2. IAQ Assessments - Quantitative or Qualitative Standards 4

1.1.3. IAQ Assessments/Investigations – Reactive or Proactive 4

1.2. Objective 5

1.2.1. Background 5

1.2.2. Specific Objectives 7

2.0 Literature Review 9

2.1 Recent IAQ Assessment Research 9

2.2. IAQ Standard/Guidelines 22

2.2.1. BOMA IAQ Guiding Documents 22

2.2.1.1. The BOMA BESt Program: BOMA Building Environmental Standards Version 2 (Revised July 2013) 22

2.2.1.2. BOMA BESt Assessment Overview: BOMA Building Environmental Standards OFFICE Module (Revised August 2013) 23

2.2.2 American National Standards Institute/American Society of Heating, Refrigeration and Air-Conditioning Engineers (ANSI/ASHRASE) 23

2.2.2.1 ANSI/ASHRAE History 23

2.2.2.2 ANSI/ASHRAE, Standard 55 – 2013: Thermal Environmental Condition for Human Occupancy (2013b) 24

2.2.2.3 ANSI/ASHRAE, Standard 62.1 – 2013: Ventilation for Acceptable Indoor Air Quality (2013a) 25

2.2.2.4 ANSI/ASHRAE, Indoor Air Quality Guide, Best Practice for Design, Construction and Commissioning (2009) 27

2.2.3 Federal-Provincial Advisory Committee on Environmental and Occupational Health, Indoor Air Quality in Office Buildings: A Technical Guide (1995) 28

2.2.4 Government of Alberta, Environmental Public Health Indoor Air Quality Manual: A Guide for Environmental Public Health Professional (2012) 29

2.2.5 Government of Alberta, Employment and Immigration, Indoor Air Quality Toolkit (2009) 29

2.2.6 Government of Alberta, Indoor Air Quality: Mould in Indoor Environments Risk Assessment and Management Program Handbook, Alberta Infrastructure and Transportation (June 2006, Revised June 2007) 30

2.2.7 National Standards of Canada, Psychological Health and Safety in the Workplace – Prevention, Promotion, and Guidance (2013) 30

2.3. Methods of Applying IAQ Standards and Guidelines 32

2.3.1. BOMA BESt® Version 2, Application Guide (Revised August 2014) 32

2.3.2. BOMA BESt Assessment: Office Buildings, (June 2009) 33

2.3.3. Federal-Provincial Advisory Committee on Environmental and Occupational Health, Indoor Air Quality in Office Buildings: A Technical Guide (1995) 34

2.3.4. Government of Alberta, Environmental Public Health Indoor Air Quality Manual: A Guide for Environmental Public Health Professionals (2012) 35

2.3.5 Government of Alberta, Employment and Immigration, Indoor Air Quality Toolkit (2009) 36

2.3.6. Government of Alberta, Alberta Infrastructure, Indoor Air Quality: Mould in Indoor Environments Risk Assessment and Management Program Handbook (June 2006, Revised June 2007) 37
2.4. Overview of Cited IAQ Standards and Methods 38
2.4.1. Standards/Guidelines 39
2.4.2. Methodology 39
3.0. Preliminary Requirements for the BOMA IAQ Assessment Methodology 42
3.1. Perspectives 43
3.1.1. Positivist 43
3.1.2. Constructivist 44
3.1.3. Pragmatism 45
3.2. Epidemiological Study Designs 47
3.3. Field Experience 48
3.4. Proposed Cross-Sectional, Convergent-Parallel, Mixed-Method Study Design 49
4.0. Description and Evaluation of the Components 56
4.1. Quantitative Standards/Methodologies 56
4.1.1. Outdoor Air Quality 56
4.1.2. Building Operator 56
4.1.3. Review Documents 57
4.1.4. Mechanical Room (s) – Condition of Air Handling Units (AHUs) 58
4.1.5. Occupied Areas 59
4.1.5.1. Comfort Parameters 60

4.1.5.2. Dust 62

4.1.5.3. Supply Airflow and Air Pressurization 62

4.1.5.4. Formaldehyde, Ozone, Total Volatile Organic Compounds (TVOC) and Other Observations 63

4.2. Qualitative Standards/Methodologies 64

4.2.1. Qualitative Descriptive 64

4.2.2. Assessor Engagement 64

4.3. Phases of the Proposed Cross-Sectional, Convergent-Parallel, Mixed-Method Study Design 67

4.3.1. Determining IAQ Test Locations (Spot Tests) 67

4.3.1.1.Random Spot Testing 69

4.3.1.2. Non-Random Spot Testing 71

4.4. Proposed Cross-Sectional, Convergent-Parallel, Mixed-Method Study Design – Results 72

4.4.1. Preliminary Results 73

4.4.2. Final Report 73

4.5. Proposed Cross-Sectional, Convergent-Parallel, Mixed-Method Study Design - – Assessor Self Checks for Quantitative and Qualitative Validity and Reliability 75

4.5.1. Quantitative Self-Checks 75

4.5.2. Qualitative Self-Checks 76

5.0. Discussion and Recommendations 78

5.1. Discussion 78

5.1.1. Overview of the Strengths of the Methodology 87

5.1.2. Overview of the Weaknesses of the Methodology 88

5.2. Recommendations 92

6.0. References 96

7.0. Appendices 104

Appendix A Government of Alberta, Spring 2011, Alberta Infrastructure, Initial BOMA IAQ Assessment Guide 105

Appendix B Government of Alberta, 2015, Records Listing of 2011 – 2014 BOMA IAQ Assessments 106

Appendix C Government of Alberta, February 2, 2012, Alberta Infrastructure, Revised BOMA IAQ Assessment Guide 108

Appendix D Government of Alberta, August 8, 2013, Alberta Infrastructure, Revised BOMA IAQ Assessment Guide 109

Appendix E Ncube and Riffat, 2012, Indoor Air Quality Questionnaire 110

Appendix F ASHRAE, 2013b, Standard 55-2013, Metabolic Rates for Typical Tasks 114

Appendix G ASHRAE, 2013b, Standard 55-2013, Clothing and Garment Insulation Values 115

Appendix H	ASHRAE, 2013b, Standard 55-2013, Graphical Representation of Comfort Zone and Acceptable Ranges of Operative Temperature and Average Air Speed	117
Appendix I	ASHRAE, 2013a, Standard 62.1-2013, Table B-1	119
Appendix J	ASHRAE, 2013a, Standard 62.1-2013, Table B-2	120
Appendix K	ASHRAE, 2013a, Standard 62.1-2013, Table B-3	123
Appendix L	ASHRAE, 2009 Indoor Air Quality Guide, Best Practice for Design, Construction and Commissioning, Table of Contents	125
Appendix M	Federal-Provincial Advisory Committee on Environmental and Occupational Health, 1995, Indoor Air Quality in Office Buildings: A Technical Guide, Table 1	127
Appendix N	Federal-Provincial Advisory Committee on Environmental and Occupational Health, 1995, Indoor Air Quality in Office Buildings: A Technical Guide, Table 2	128
Appendix O	Federal-Provincial Advisory Committee on Environmental and Occupational Health, 1995, Indoor Air Quality in Office Buildings: A Technical Guide, Table 3	129
Appendix P	Government of Alberta, 2012, Environmental Public Health Indoor Air Quality Manual, Various Guidelines, Standards, Figures and Tables	130

Appendix Q Government of Alberta, 2012, Environmental Public Health Indoor Quality Manual, Schematic of a Typical HVAC System. 176

Appendix R Government of Alberta, 2009, Employment and Immigration, Indoor Air Quality Toolkit, Standards and Guidelines 177

Appendix S Government of Alberta. June 2006 (Revised June 2007), Alberta Infrastructure, Indoor Air Quality Guidelines, Appendix 3 181

Appendix T Government of Alberta, 2012, Environmental Public Health Indoor Quality Manual, Phases, Questions and Walk-Through Guidelines 182

Appendix U Government of Alberta, August 2009, Employment and Immigration, Indoor Air Quality Toolkit, Sample Health Survey 214

Appendix V Government of Alberta, August 2009, Employment and Immigration, Indoor Air Quality Toolkit, Assessment and Resolution Flow Chart 217

Appendix W Government of Alberta, June 2006 (Revised June 2007), Alberta Infrastructure, Appendix 1: IAQ Response Process and Walk-Through Checklist 218

Appendix X Creswell, J. W. and Clark, V.L.P., 2011, Flowchart of the Basic Procedures in Implementing Convergent Design, Figure 3. 220

Appendix Y	Government of Canada, 2013, Canadian Centre for Occupational Health and Safety, OSH Answers Fact Sheets, Carbon Monoxide	221
Appendix Z	Overview of Proposed BOMA IAQ Assessment Methodology	225

List of Tables

Table 1 Summary of Indoor Air Quality Parameters Monitored 14

Table 2 Multidimensional Checklist for Evaluating Indoor Air Quality 17

List of Figures

Figure 1	Nine Point Scale Indoor Air Quality Questionnaire.	10
Figure 2	Mean Concentration of TVOCs in the Indoor and Outdoor Environments During the Spring and Summer Seasons.	11
Figure 3	Mean Concentrations of TVOCs in the Indoor and Outdoor Environments During the Autumn and Winter Seasons.	11
Figure 4	Inorganic Compounds in Various Areas of a Printery: A) Presser Section; B) Bookbinding Section; C) Dispatch.	12
Figure 5	Study Framework for Indoor Air Quality Investigation.	13
Figure 6	Indoor Air Quality Audit Methodology.	19
Figure 7	Triangulation Triangle, Convergent Findings.	51
Figure 8	Triangulation Triangle, Divergent Findings.	52

List of Symbols

AI	Alberta Infrastructure
AHU	Air Handling Unit
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
BEU	Building Environment Unit
BOMA	Building Operators Management Association
C	Celsius
GOA	Government of Alberta
HVAC	Heating, Ventilation and Air Conditioning
IAQ	Indoor Air Quality
OSHA	Occupational Safety and Health Administration
NIOSH	National Institute of Occupational Safety and Health
TSB	Technical Services Branch
WHO	World Health Organization

1.0. Introduction and Objective

1.1. Introduction

As will be shown in the proceeding research, the concepts of quantity and quality are implicitly implied in the term Indoor Air Quality (IAQ). Built environments consist of a wide variety of materials and systems. When such items interact and age, they can readily change and emit a wide range of biological and chemical agents, as well as, various forms of energy into the surrounding air which can impact those who occupy these spaces. By measuring the responses of a large number of people within indoor environments and then constructing an acceptable range for each of the parameters, the person's qualitative or personal experience can be transformed into quantitative data.

To begin, it is important to clearly define the concepts of quantity and quality. Generally, quality is often used to indicate how good or bad something is perceived to be. When a person says their meal was bad, it means they believe it had a poor level of quality. Yet, another person can have the same meal and say it was good. In contrast, the food may go through a series of scientific tests measuring or quantifying bacteria and nutrient levels and be considered acceptable.

These examples are given to illustrate how quality appears to be a reflection of personal preference and can not only vary between people, but also within the same person, whereas quantity is a non-personal standard which does not vary. To emphasis this difference, the present research will define Quality as: *an internal, personal standard which cannot be readily measured by external means* and Quantity as: *an external, environmental standard which can be readily measured by external means.* It can then be suggested, that with quantity being inherently easier to measure, it has become a surrogate and often a replacement for quality.

It should also be re-emphasized that although quantifying qualitative experiences allows for the construction of IAQ Standards, these standards are based on the averaged experiences of the population. Because of this, it could be hypothesized that not only may an individual's personal IAQ standards not occur within the averaged range, but as more IAQ tests are performed for one person, so will the likelihood that the person's IAQ preferences not occur within all of the averaged ranges of the parameters being tested. Therefore, if only quantitative measures are being taken to represent the Indoor Air Quality, it is possible that the perceived IAQ of some of the people, even if they are healthy, will be deemed unacceptable; and it may also be possible that the IAQ of those that are not healthy is measured as being acceptable.

1.1.1. Working Definition of Indoor Air Quality (IAQ)

In order to measure or quantify IAQ, the process must be guided by a clear and concise definition of indoor air quality. In 1986, WHO described Indoor Air Quality as, 'Physical and chemical nature of indoor air, as delivered to the breathing zone of building occupants, which produces a complete state of mental, physical and social well-being' (WHO, 1986). In comparison, the American National Standards Institute/American Society of Heating, Refrigeration and Air Conditioning Engineers (ANSI/ASHRAE) Standard 62.1-2013 (2013a) defined acceptable IAQ as: 'Air in which there are no known containments at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction.' Furthermore, ANSI/ASHRAE's Standard 55-2013 (2013b) implies thermal comfort is also an important aspect of IAQ. The WHO definition suggests IAQ is a result of many aspects of a person and is not easily defined, whereas the ANSI/ASHRAE definition is more determinate and is guided by specific ranges. Nevertheless, health and comfort appear to be fundamental concepts of IAQ.

Due to these opposing definitions, it seems prudent to compose a definition highlighting the seminal aspects of both definitions for this research. To this end, by applying both concepts of quality and quantity a more comprehensive definition is formed; with the former emphasizing the WHO definition, and latter more akin to ANSI/ASHRAE standards. This means the definition of IAQ should not primarily rely on measurements (quantity) without considering the context and perceptions (quality). For example, while it is possible to define comfort in engineering terms - such as flow rate, temperature and humidity - Evans and Cohen (1987) found many other factors can affect well-being. Amongst these elements, cited works by Delongis et al. (1982) and Kanner (1981) concluded 'daily hassles', such as environmental events and interpersonal problems can greatly affect comfort. Therefore, daily hassles are prominent and can readily affect personal experiences within any environment, including the indoors; implying a person's reaction to them needs to be considered when measuring IAQ.

Based on this information, the definition of Indoor Air Quality needs to be more inclusive. While the WHO (1986) definition is well-constructed, it emphasizes only those elements in the breathing zone and the ANSI/ASHRAE (2013a and b) definitions are too deterministic. In keeping with what may or may not affect a person, and how they may respond to it, the following IAQ definition is proposed for this research: '*A person's complete response to elements within an indoor environment which may cause them excessive stress, and which may attribute to their acceptance of the indoor air*.' In response, it could be argued this definition is vague and unhelpful, allowing anything to cause anything else. However, as the course of this thesis will argue, with IAQ being a complex construct, not only because of the variety of biological, chemical and forms of energy contained within it, but also the occupant's diverse reactions to it, a meaningful definition needs to consider all facets of the environment.

1.1.2. IAQ Assessments - Quantitative or Qualitative Standards

The focus of an Air Quality Assessment predetermines which standard or preferred state the measurements are compared against. The focus of what is referred to as a (1) building-centered assessments is to determine if quantitative standards are being met. This may be done to measure if the building's mechanical systems are working within design specifications. The next type is designated as an (2) occupant-centered assessment, where the assessor undertakes an investigation to determine if both the buildings quantitative IAQ measurements, as well as, the occupant's individual standards of acceptable Indoor Air Quality are being met. The last type is (3) Financial Assessment to determine whether health outcomes such as increased sick days and increased WCB claims within a building could be associated with inadequate IAQ. As such, each type of assessment is based on a particular focus and a particular standard, but it does not mean an actual inspection will only employ one (1) objective.

1.1.3. IAQ Assessments/Investigations – Reactive or Proactive

Along with specifying the objectives of an Indoor Air Quality Assessment and their associated standards, is the question of cause and effect. Based on Alberta Infrastructure Guidelines (Government of Alberta, June 2006) reactive and proactive are the two (2) major types of Indoor Air Quality Assessments. A reactive IAQ Assessment is in response to specific building occupant complaint(s). In these circumstances, there may be one (1) or more symptoms expressed by one (1) or more occupants that may be related, information requiring a response in a specific part(s) of the building. Depending on how specific the symptoms are, as well as the characteristics of the environment, the more pre-determined the response will be. There is also the proactive type of IAQ Investigation that is not complaint-driven. Although a building operator or other third party has no specific concern in any described area of the building, the assumption is they would like the general air quality checked against the standard to know if it meets the standard and what actions they should take if there is a deficiency.

1.2. Objective

1.2.1. Background

In early 2011, the Building Environment Unit (BEU) of the Technical Services Branch (TSB) of Alberta Infrastructure (AI) was contacted by a department within the AI Property Management Division, Facilities Environmental, to conduct proactive IAQ assessments in Alberta Government Buildings. The specific request relayed to the BEU to conduct IAQ assessment was from representatives of the Building Operators Management Association of Canada (BOMA) BOMA BESt Energy and Environmental Program. The intent of the assessments was for GOA buildings to achieve BOMA BESt designations. More specifically, as stated in the 2010 BOMA BESt Energy and Environmental Report, the purpose of the assessments was to generate ratings and recommendations for building improvement (BOMA, 2010).

At that time, the BOMA process involved three (3) parts including: Assessment, Education and Verification (BOMA, 2010). According to this document, assessments involved the building operator/owner filling out 175 questions for the following six (6) different areas: Energy (35%); Water (8%), Waste Reduction and Site (11%), Emission and Effluents (17.5%), Indoor Environment (17.5%), and Environmental Management System (11%). The BOMA Report (2010) indicated that education would occur by guiding the building managers and their teams through the building review from an environmental prospective. Verification would take place when the applicants' submitted information was audited by a third-party.

In view of this framework, the BEU was being tasked to undertake verification. However, since verification is a proactive process, and the BEU mostly performed reactive or complaint-driven investigations, a methodology had to be developed. In order to start the process, at the beginning of the research period (PHASE I) an IAQ Assessment BOMA Protocol (Appendix A) was co-developed by this researcher in the Building Environment Unit based on previous field experience and the following statement given in the already cited BOMA document (2010):

> Environmental management of a building needs to be done in comprehensive way that also considers the health and comfort of occupants . . . This includes indoor ventilation, filtration and humidification. . . control of pollutants at source . . .

Because the concepts of health and comfort are mentioned in this document, and they are associated with the indoor environment, it was assumed by this researcher that the Building Operators Management Association understood both quantitative and qualitative standards were involved in assessing a building's IAQ and in keeping with the offered working definition of Indoor Air Quality stated in this thesis.

In overview, from March 2011 until late 2014, approximately 50 BOMA Indoor Air Quality inspections were performed by the Building Environment Unit of Alberta Infrastructure (Appendix B). During this period, the initial PHASE I Protocol (Appendix A) was implemented and then modified as needed based on the lessons learned by the assessment team. This information resulted in updated protocols (Appendix C and D) which were used during PHASE II of the assessments which lasted until late 2014. The following is a brief list of the lessons learned by this researcher, most of which were rooted in the assessor or building operator not clearly understanding the difference between quantitative and qualitative standards:

1) Quantitative IAQ standards, and their set variables, including the acceptable ranges, encompass and define the concepts of 'health' and 'comfort';

2) Deviations beyond acceptable ranges in the quantitative IAQ variables may or may not be the major contributors to IAQ complaints and concerns;

3) IAQ Assessors can acquire and use the necessary IAQ equipment to measure and clearly define these IAQ variables;

4) The IAQ variables measured on the day of inspection reflect conditions that lead to the initial IAQ complaint;

5) Only quantitative observations are empirical, and therefore scientific, implying any other data, such as qualitative measurements, are perceived to be less valid;

6) Quantitative variables are perceived to be more representative of the IAQ than the occupants' qualitative perceptions;

7) Indoor Air Quality (IAQ) Questionnaires are the only acceptable means of acquiring qualitative data.

1.2.2. Specific Objectives

The Main objective of this thesis is to propose an occupant-centered, proactive methodology for conducting Building Operators Management Association Indoor Air Quality Assessments (BOMA IAQ Assessment) of the Government of Alberta (GOA) buildings. The proposed methodology will incorporate the acquired experience and lessons learned by this researcher in the Building Environment Unit during the initial three (3) years of conducting BOMA IAQ Assessments in the GOA buildings. This methodology will be based on the premise that the acquisition and analysis of both quantitative and qualitative data is vital in not only understanding the building's ventilation and mechanical system's ability to provide a healthy and comfortable environment to the occupants, but also the building operator and associated staff to maintain them. This thesis entails PHASE III of the research, which proposes a cross-sectional, convergent-parallel, mixed-method study design as a means to achieve this goal. This method is a starting point for the formalization of a BOMA IAQ Assessment process that can be applied to the GOA buildings throughout Alberta. The thesis will evaluate the strengths and weakness of this proposed methodology and offer a number of recommendations.

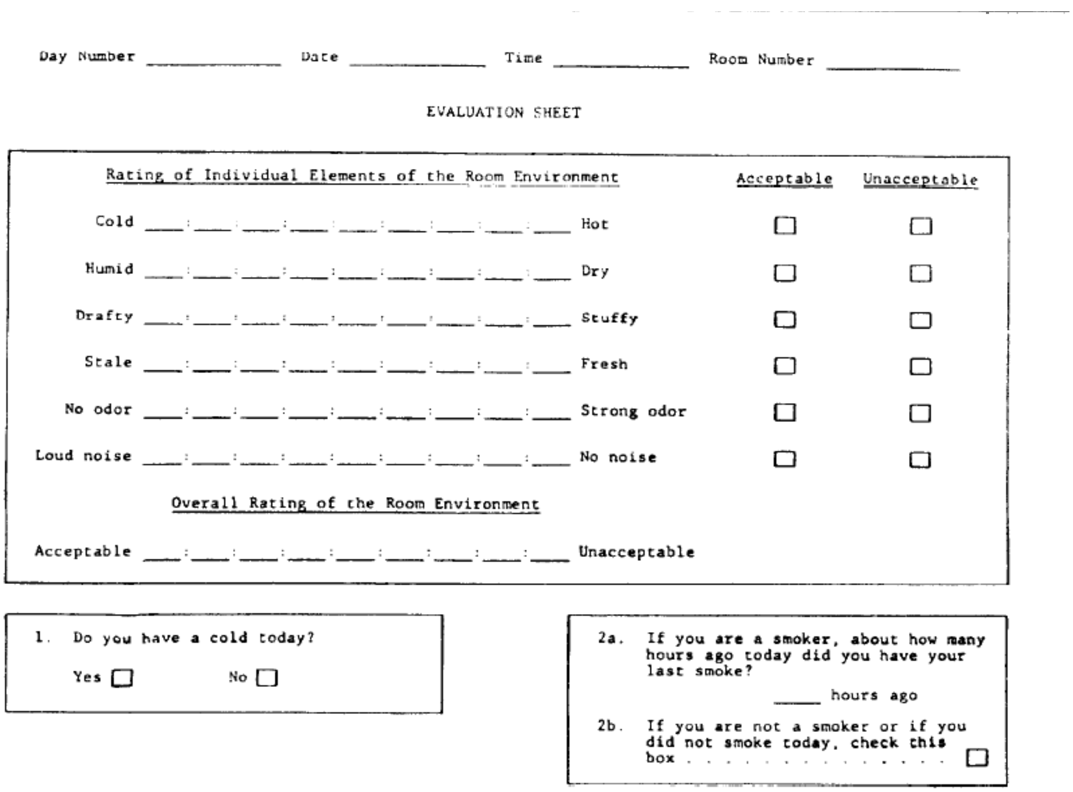
Implementing the proposed methodology can achieve primary and secondary goals. A primary goal of this research is to enable the analysis and interpretation of acquired quantitative and qualitative data to produce recommendations to improve the Indoor Air Quality of the assessed buildings. The goal is not to meet all of the occupant's IAQ requirements, but to acquire a sufficiently comprehensive sample so as to represent the majority of the occupant's IAQ concerns in the building, and then to consider their possible impact on the health and comfort of all of the building's occupants. Those factors appearing to be related to the building, and can be corrected, are then listed and recommendations to correct them are given to the building operator and associated Alberta Infrastructure staff. A secondary goal is to group together the data from the individual buildings to look for common associations between general causes and potential impacts. If such commonality is found, it would be recommended this information is proactively applied to GOAs buildings that have not been assessed.

2.0. Literature Review

2.1. Recent IAQ Assessment Research

Spengler and Sexton (1983) highlighted the need to measure conditions inside buildings which may be related to the occupant's health. In their article, the researchers comment that since outdoor and indoor air has different compositions and concentrations of airborne chemicals, and with people spending a majority of their day indoors, there is a need to emphasize the importance of the affects of indoor air pollution on the occupants and means to improve air quality. After analysing potential hazards in the indoor environment, and acknowledging the complexity of the sub-systems involved, the researchers concluded a comprehensive evaluation was required, including measuring: emission sources, dilution, indoor concentrations, human activity patterns, exposures and health effects. In respect to considering qualitative IAQ standards, the researchers stated the importance of obtaining information about individual perceptions of indoor air quality. Nevertheless, Spengler and Sexton (1983) did not detail how such measurements should be taken, or if the response should be reactive or proactive in nature or both.

In the same year, Turiel et al. (1983) published an article concerning Indoor Air Quality Assessments as a result of occupant complaints in an office building. In response to occupants' symptoms in a San Francisco office building, including eye, nose and throat irritation, the investigators believed IAQ could be quantified either directly by measuring the concentrations of indoor air pollutants, or by measuring the ventilation rate, and then inferring IAQ from it. The parameters measured included: temperature, humidity, carbon monoxide, carbon dioxide, nitrogen dioxide, formaldehyde, other organics, particulates, odour and microbial burdens. Along with these parameters, the investigators gave the occupants a small nine-point scale questionnaire (Fig. 1) to obtain subjective information on odour perception and other indoor environmental factors. Each of the parameters was rated by the occupants in terms of acceptability which was then compared to an outside group's perception of odour exposed to the same air. This qualitative information was used to determine if the ventilation rates were acceptable.



Day Number ______ Date ______ Time ______ Room Number ______

EVALUATION SHEET

Rating of Individual Elements of the Room Environment			Acceptable	Unacceptable
Cold	__:__:__:__:__:__:__:__:__	Hot	☐	☐
Humid	__:__:__:__:__:__:__:__:__	Dry	☐	☐
Drafty	__:__:__:__:__:__:__:__:__	Stuffy	☐	☐
Stale	__:__:__:__:__:__:__:__:__	Fresh	☐	☐
No odor	__:__:__:__:__:__:__:__:__	Strong odor	☐	☐
Loud noise	__:__:__:__:__:__:__:__:__	No noise	☐	☐

Overall Rating of the Room Environment

Acceptable __:__:__:__:__:__:__:__:__ Unacceptable

1. Do you have a cold today?

Yes ☐ No ☐

2a. If you are a smoker, about how many hours ago today did you have your last smoke?

_____ hours ago

2b. If you are not a smoker or if you did not smoke today, check this box . . . . ☐

Figure 1 - Nine Point Scale Indoor Air Quality Questionnaire (Turiel et al., 1983).

With time, researchers have discovered other compounds can influence Indoor Air Quality. Posniak et al. (2005) measured the mean indoor air concentrations of Volatile Organic Compounds (VOCs) in 50 offices in five (5) office buildings in Warsaw. In all of the buildings, the Indoor VOC levels were higher than outdoor levels throughout the year, including those with air conditioning, mechanical and natural ventilation (Fig. 2 and 3). In addition, the researchers used this information to determine if the subjective information could be used to assess the air purity in the office. In their conclusion, the authors wrote the level of indoor VOCs were high enough to cause the perception of sick building syndrome in some of the workers. The authors were also concerned with an apparent absence of health-based Indoor Air Quality Standards for the office working environment.

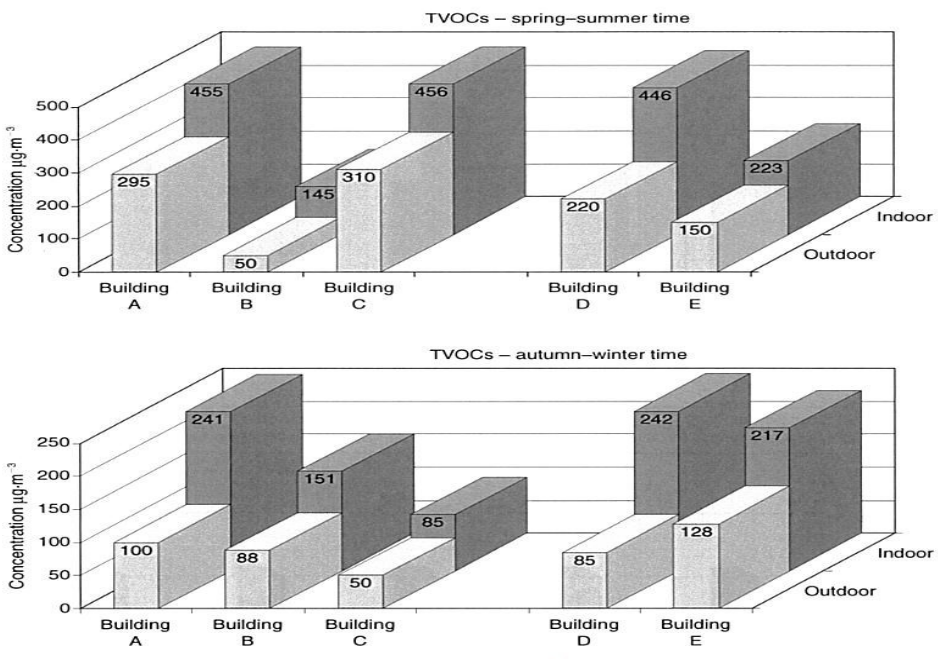


Figure 2 - Top Figure Shows Mean Concentration of TVOCs in the Indoor and Outdoor Environments During the Spring and Summer Seasons (Posniak et al., 2005).

Fig. 3: Bottom Figure Shows Mean concentrations of TVOCs in the Indoor and Outdoor Environments During the Autumn and Winter Seasons (Posniak et al., 2005).

Saraga et al. (2011) research in various built environments highlights the complex nature of Indoor Air Quality and how it is affected by numerous factors. In various buildings, including a museum, printing shop and an office building, measured concentrations of airborne compounds depended not only on the air exchange rate of the mechanical systems, but also the building's design and orientation. Variations in ambient levels of organic compounds within the Print Shop are shown in Figure 4. The researchers concluded that the physical layout and items within the space can affect the IAQ and such be accounted for during the assessment. This implies the number of test locations in which air samples are taken should not be based primarily on the floor area. If this is done, the complexity of the indoor environment may be passed over, creating a situation whereby important elements of the building that may influence quality of the air could be overlooked. This research stresses the importance of choosing the test locations and the time the testing is done based on onsite observations.

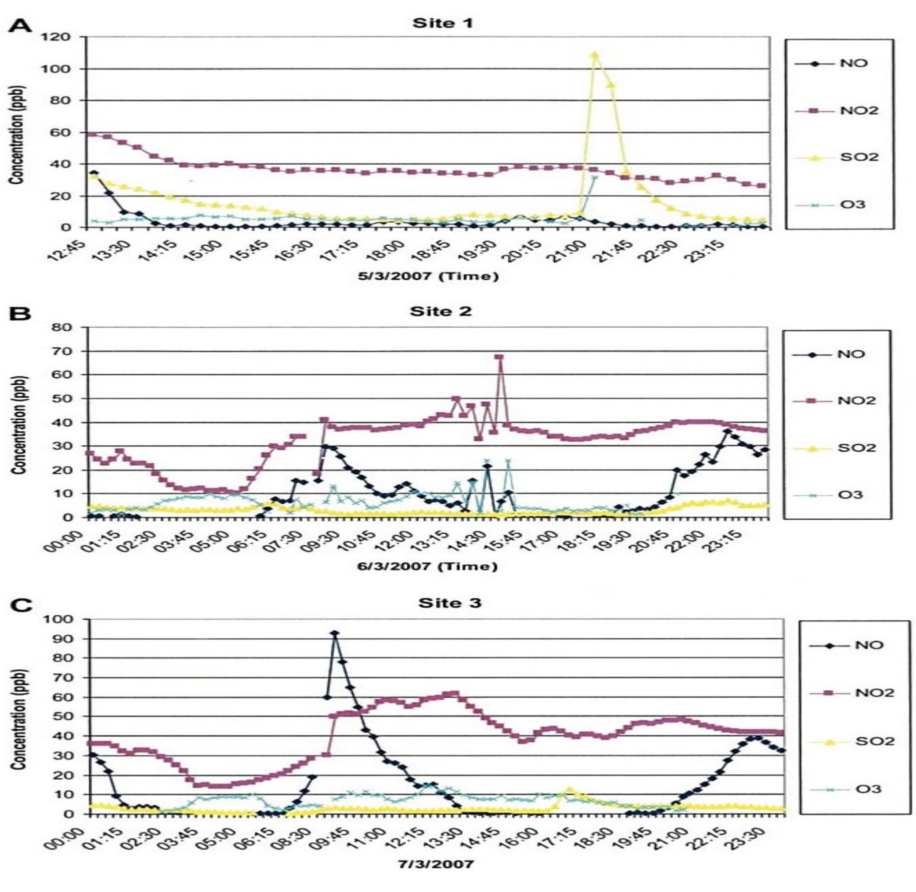


Figure 4 - Inorganic Compounds in Various Sections of a Printery: A) Presser; B) Bookbinding; C) Dispatch. (Saraga et al.,2011).

Other studies support the importance of formalized IAQ standards and methodologies for non-industrial work places. In a paper by Ismail et al. (2010), Indoor Air Quality of two (2) Malaysian high rise buildings was measured. The researchers claimed the methodology they developed and used was both quantitative and qualitative, with the qualitative aspect of the study design being described as a 'walk-through approach' which included interviews (Fig. 5[1]). However, upon closer inspection, the purpose of the walk-through did not appear to be to interview the occupants of these buildings, but to identify potential indicators of IAQ issues. The factors described by the authors included: visual evidence of moisture problems or microbial contamination, the presence of unusual odours, potential and actual locations of specific pollutant sources, pollutant pathways and pressure differentials, review of the ventilation air conditioning systems, and evidence of excessive settled dust.

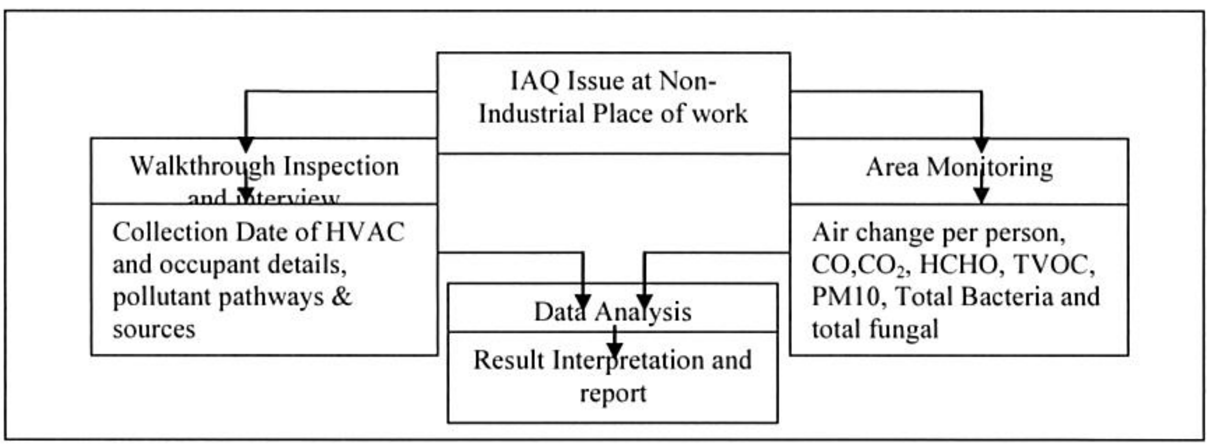


Figure 5 - Study Framework for IAQ Testing (Ismail et al., 2010).

Although the researchers list of factors was comprehensive (Table 1), including pressure differences between the test areas, it is somewhat vague. Since the authors did not clearly define what they consider to be quantitative and qualitative measurements, there is no way to know if

[1] Typographical error in the upper box in the first column was present in the original figure.

they were able to adequately perform such testing. Furthermore, if it is assumed the term qualitative is supposed to mean perception and it is of the assessor's and not of the regular occupants of the building, the authors did not state why the assessor's perceptions were more important than the occupants'. Moreover, if we accept the suggestion quantitative standards are external to the perception of those who are being tested, then the interview was actually quantitative and not qualitative.

Table 1. Summary of Indoor Air Quality Parameters Monitored (Ismail et al., 2010).

Item	Parameter	Reference Method	Equipment
1	CO, CO_2, TVOC, RH and Temperature.	Direct Reading	IAQ Rae Multi-gas detector c/w RH and Temperature sensors.
2	Formaldehyde	Direct Reading	Formaldemeter
3	Respirable particulates (PM10)	NMAM 0600	Dust Track Meter
4	Air Flow and Ventilation Rate	ASHRAE 62-2007	Flow meter Velocycal CFM
5	Microbial; Total bacteria and Total fungi	NIOSH BIOLOGICAL SAMPLING NMAM 0800	SKC Microbiological Sampler

Legend

- ***NMAM;*** *NIOSH Manual Analytical Method*
- ***USEPA;*** *United States Environmental Protection Agency*
- ***ASHRAE:*** *American Society of Heating, Refrigeration, and Air Conditioning Engineering*

Researchers in Hong Kong gave an overview of the importance of adequately measuring IAQ, including increased involvement from the occupants (Chan, 2011). Chan (2011) cites a Hong Kong Environment Protection Department (2003) study which reports poor IAQ can cause a number of illness; including absenteeism and lower worker productivity. Along with describing a detailed list of items within the workplace that can emit chemicals, Chan (2011) cited the World Health Organization (2000) who estimated up to 30% of modern commercial buildings have substandard IAQ. Chan's research involved taking IAQ measurements at a local learning centre and commercial building, including the occupant's feedback with questionnaires before and after the assessment to gauge IAQ improvement based on recommendations made during the initial assessment. In addition, the researchers tracked the number of occupant IAQ complaints. However, it must be noted the questionnaires were prepared to solicit feedback from selected occupants, based on, amongst other measures, those with the highest rate of complaints. Therefore, the researchers assumed those who complained the most must also have had the worse Indoor Air Quality issues. Nevertheless, the authors concluded IAQ issues were very complex, and due to this, require the involvement of all the stakeholders through good communication.

Within the Chan (2011) article, the authors cited a 1991 document authored by the U.S.EPA and US Department of Health, stating Indoor Air Quality assessments should be inclusive. The U.S. EPA and NIOSH (1991) article stated poor IAQ can reduce productivity due to occupant discomfort and can strain the relations between landlords and tenants, employers and employees. In an overview of Section 3 of the U.S EPA and NIOSH (1991) document, it is stated effective communication is required of all parties affected by Indoor Air Quality, including the operator, to clarify responsibilities and increase the likelihood of finding and correcting potential IAQ problems. Furthermore, the researchers believed even small IAQ problems not adequately resolved through cooperative problem solving could cause the occupants to become frustrated and mistrustful, leading to disruptive and potentially costly consequences. These findings imply Indoor Air Quality Assessments should include input from the people who are mostly affected by the issues, namely the occupants. Their involvement would not only include defining the issues and measuring them, but also possible ways to resolve them. Therefore, the U.S. EPA and NIOSH view effective communication as a key aspect of a productive and meaningful IAQ investigation, requiring input from the occupants.

Other researchers believe it is necessary to devise a multidimensional action checklist to fully evaluate the Indoor Air Quality. According to Syazwan et al. (2012), the lack of assessment activities and studies on Indoor Air Quality (IAQ) in many non-industrial workplaces, especially in small and medium enterprises, have been identified as problems requiring a solution, and countermeasures need to be discussed at both the national and worldwide levels for their resolution. Syazman et al. (2012) saw using a proactive comprehensive checklist as an effective tool because many commercial building operators do not conduct inspections until there is a complaint. To these researchers, it was more logical to conduct a risk assessment of the indoor environment to pinpoint areas which are, or could become IAQ concerns than waiting for complaints to drive the process. Their checklist (Table 2) consisted of seven (7) core elements, including both quantitative and qualitative elements. Element Six is Perception of Indoor Air Quality, which covers perceived IAQ concerns as stated by the occupants, including evidence of occupant complaints and discomfort, with the assessor describing the general perceived feeling of the occupants toward working in the particular workplace. However, the authors did not define the method (s) used to acquire and describe the occupants' perceptions.

While most studies use the term Indoor Air Quality to indicate the health and comfort of the indoor environment, other researchers suggest a more comprehensive term. Ncbue and Riffat (2012) devised a formula which computed a numerical output referred to as Indoor Environment Quality Index (IEQ_{index}) consisting of: Thermal Comfort (TC), Indoor Air Quality (IAQ), Acoustic Comfort (AC) and Lighting (L). The IAQ subindex was defined as the occupant's satisfaction with the ventilation and levels of contaminants in their work areas. As part of their methodology, the researchers offered a correlational method called the Passive Observational Method (POM), using field measurements and a comprehensive questionnaire (Appendix E) to determine the relative importance of each of the terms in the $IEQ_{index.}$ Represented as a formula, researchers weighted the different factors in the following way (Ncbue and Riffat, 2012):

$$IEQ_{index} = 0.30 \times TC_{index} + 0.36 \times IAQ_{index} + 0.16 \times L_{index} + 0.18 \times Acc_{index}.$$

Table 2. Multidimensional Checklist for Evaluating Indoor Air Quality (Syazman et al., 2012).

Code	Core areas	Section	Technical areas/term	Number of essential items	Example of the items
I.	General indoor environment	A	Odor and general visible inspection during walkthrough	15	**Assessor inspection** Asking about the odor of the workplace whether acceptable or not Determine basic observed condition of workplace (office) such as leakage, ventilation diffuser, and possible pollutants exist
II.	Human exposure and comfort level	B	Estimation of the occupancy rate in the work area/s	2	**The identification of workspace requirement** Evaluating the space within the workplace and any evidence of unsuitable conditions
		C	Utilized the comfort and perceived indoor environmental problem (if any)	9	**Evidence of the indoor environment conditions** Characterization of the location and condition associated with the risk of indoor air pollutants and possible hazard to workers Evaluation of the workers' perception regarding the indoor environment condition by looking at the behavioral practice toward adapting the indoor environment
III.	Potential source of contaminants	D	Occupant attitude toward smoking and other common source of pollutants	4	**Establishing the pollutants inventory** Establishing the pollutants inventory (including smoking activity) to easily identify the possible pollutants that may influence the indoor air quality in workplace
		E	Potential prescribed activities	8	**Identification of activities that may pose health risk effects during normal building operations** Tracing any prescribed activities leading to health-related risk: eg, renovation and installation of new air-conditioning system
IV.	Ventilation and air-conditioning system	F	Evaluation of ventilation and air-conditioning system condition as manufactured specification	18	**Gathering information on mechanical ventilation and air-conditioning system** Find useful information about the operation and maintenance of mechanical ventilation and air-conditioning system that serves the occupant workspace Collection of evidence that shows possible risk of generating poor indoor air quality
V.	Perception of indoor air quality in outdoors	G	Comparison of air quality in outdoors	3	**Gathering information regarding outdoor air status** Provide sufficient evidence regarding the outdoor air condition that may influence indoor environment
VI.	Perception of indoor air quality in indoors	H	Perceived indoor air quality stated by occupants	5	**Evidence of occupant complaint and discomfort** Find the general perceived feeling by the occupant toward working in the particular workplace
VII.	Industry Code of Practice on Indoor Air Quality 2010	I	Understanding of indoor air quality-related guideline	7	**Understanding about the related regulation** Promote health and safety activities that can improve the indoor air quality in workplace
	Sum		9	71	

These weightings imply IEQ is most strongly influenced by IAQ and least by lighting. In conclusion, the researchers stated the Indoor Environment Quality Index had value because it relies on empirical data as well as the occupants' subjective evaluations. However, since the weightings were based on a limited number of buildings, any conclusion these researchers offered may not be easily generalized to other types of buildings.

Furthermore, in an effort to quantify the quality of the environment conditions, Syzman et al. (2012) appear to have oversimplified some of the IAQ dimensions. First, these researchers did not consider the question of whether Thermal Comfort is the only means of measuring comfort. In addition, the IAQ Questionnaires (Syazman, 2012) asked about the occupants' perception at the time of the survey and not about previous time periods. This is a concern because the amount of time it took for the assessors to conduct the IAQ testing represented a very small fraction of the total time the occupants have been inside the building. Therefore, the likelihood of their questionnaire or even the measuring equipment accurately capturing events that may affect and reflect the building's IAQ is inherently low. It is very important to realize the built environment is very dynamic, not only changing due to the building's mechanical system's ability to respond to fluctuations in its input parameters, but also as a result of the activities of the occupants. Any methodology used to measure such a dynamic system has to be able to capture such changes.

Other researchers consider the amount of manpower and resources required to conduct the assessment as important. Asadi et al. (2013) proposed an IAQ audit methodology (Fig. 6) that was claimed to be effective because it was sufficiently comprehensive, as well as, efficient. It appears the researchers had defined efficiency as being a result of focusing the inspection in areas of the structure with identified IAQ concerns. Prior to the onsite inspection, the process started with a review of the buildings floor plans, which was then followed by a walkthrough of the building, including feedback from the occupants. This information, along with observations of the potential pollutant sources, including 'swift verification of CO_2 levels', and pre-evaluation of the hygienic and maintenance conditions of the HVAC system was then used in the third step of their methodology to determine the number and locations of the sampling locations. Although the researchers concluded the investigators needed to correlate measurements with onsite observations to quickly determine the extent of the IAQ concerns, it could be asked if such an efficient method may overlook the importance of adequately engaging the occupants. Because their paper did not describe which criteria were used to pick those who gave feedback, and in what form the feedback was given, this question was not answered.

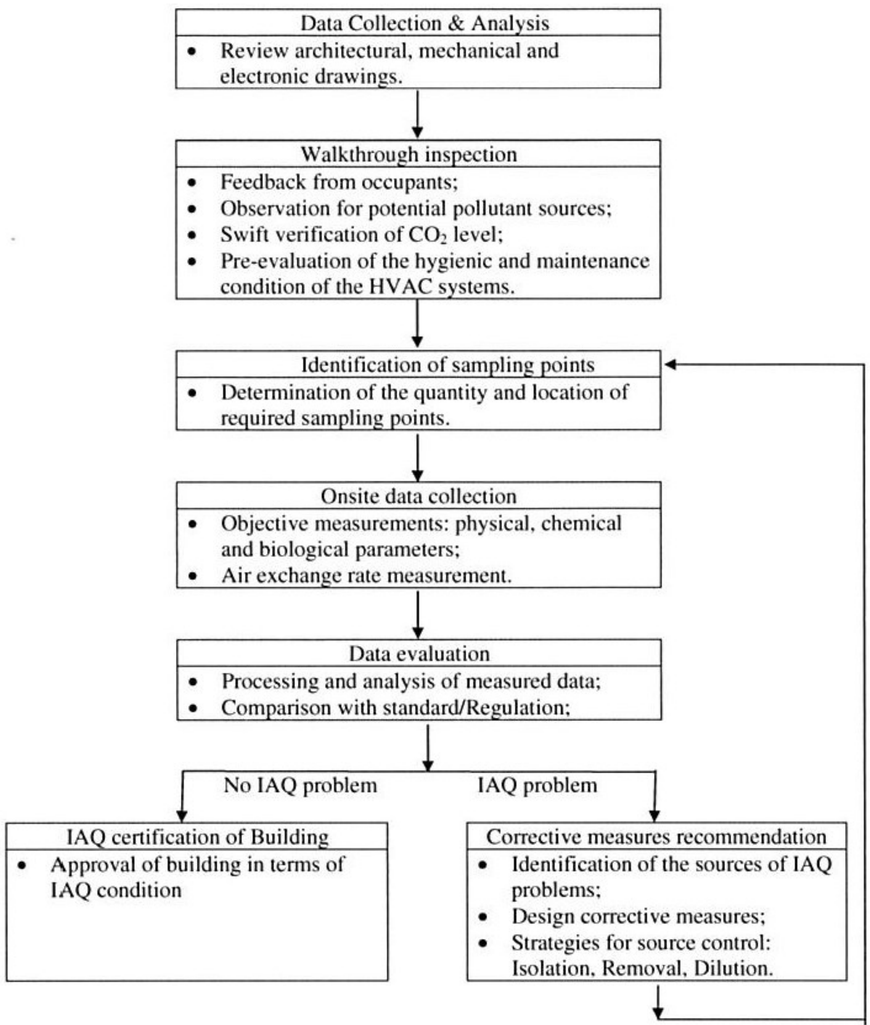


Figure 6 - Indoor Air Quality Audit Methodology (Asadi et al., 2013).

The cited studies associating quantitative with qualitative data highlight the usefulness of questionnaires in IAQ Assessments, however this form of data accruement has inherent limitations. In the introduction of this paper, quantitative and qualitative standards were differentiated based on whether the standards were internal or external to the person they were applied to. In the following excerpt, Mayan (2009) explicitly offered an understanding of the differences between the two concepts:

> Qualitative inquiry is primarily naturalistic, interpretive, and inductive. By studying naturally occurring phenomena, qualitative researchers attempt to interpret or make sense of the meaning people attach to their experiences or underlying a particular phenomenon. Qualitative researchers work inductively from individual cases (the data) and not from a pre-existing framework or a particular theory. We qualitative researchers must use creativity, sensitivity, flexibility as we try to make sense of life as it unfolds. Consequently, we are not concerned with the control of particular variables within a setting but instead invite context, complexity, and 'confounding variables'. This requires patience and the ability to live with enormous amounts of ambiguity.

As such, although a questionnaire may be well-written and include all of the physical parameters and contaminants which have been previously associated with IAQ in other buildings, and could be filled out by a majority of the occupants, the categories offered are by default pre-determined and restrictive. Due to this, a questionnaire is not naturalistic, and can interfere with the subject's ability to adequately express themselves in their own terms. It can also cause the assessor to disengage themselves from the occupants. If the assessor is lead to believe the questionnaire is an effective enough tool to gather qualitative data, they may reduce their interactions with the occupants. It could also be suggested that since the questions on the survey are based on the external standards of the researcher, and may also not be adequately representative of the unique aspects of the building being assessed, many IAQ questionnaires are more quantitative than qualitative in nature.

Research by Boxer (1990) indicated Psychological Factors are very important in a person's perception of how healthy or comfortable an environment is. One of the key messages from Boxer's work is that although a stressor within an environment may not be objectively related to a measurable attribute of the air; other factors, such as workload, job satisfaction, and levels of anxiety, can be subjectively related to the environment by the occupants. Moreover, if those who are assessing the IAQ are not aware of the association and the need to address it, it will further complicate any form of rectification.

Boxer (1990) believed many building managers upon hearing occupants' concerns only expended a minimum amount of effort in listening to and then considering the psychological ramifications of the IAQ issues. By doing this, and not accepting the unique perspective of those affected, these managers often undertook a number of unnecessary or superficial Indoor Air Quality Investigations that did not address the occupants' primary IAQ concerns. Due to the complexity of a person's interaction with, and perceptions of their environment, the assessor has to partake in more inclusive and interactive engagements with the occupants. It could be suggested interviews offer more engagement, allowing the assessor a better understanding of what the occupants might perceive as the cause of their Indoor Air Quality concerns.

Other studies indicated a relation between the psychological factor referred to as Sense of Coherence (SOC) and perception of Indoor Air Quality. SOC (Antonovsky, 1987) is the extent to which the stimuli in a person's internal or external environments may impact them and their ability to cope. As summarized by Runeson et al. (2003), this definition can be broken down into three (3) parts: 1) Is the stimuli structured, predicable, and explicable? 2) Are there resources available to the affected person to meet the demands of the stimuli? 3) Is the level of engagement with the stimuli based on demands of the stimuli and sense of worthiness of such a level of investment? Runeson et al. (2003) concluded SOC was a strong predictor of whether a building is perceived to have poor IAQ by its occupants. Moreover, Runeson and Norback (2005) concluded a person's personality is an important factor in whether medical symptoms, work satisfaction, work stress, and climate of corporation at work are reported. These researchers' findings, and the premises it was built upon, affirms the importance of a person's internal perception of their environment and how it may affect their comfort and health.

2.2. IAQ Standard/Guidelines

2.2.1. BOMA IAQ Guiding Documents

2.2.1.1. BOMA BESt Application Guide, BOMA Building Environmental Standards Version 2 (Revised July 2013)

The 2013 overview of the BOMA BESt (BOMA, 2013a) process is similar to the 2010 document which was previously described in the Section 1.2.1, Background. To assess the environmental performance of a building, the program still uses six (6) key features, including: 1) Energy; 2) Water; 3) Waste and Site; 4) Emissions and Effluent; 5) Indoor Environment; and 6) Environmental Management Systems. As of early 2015, Version 2 is the latest BOMA guide, and includes an online assessment with three (3) core elements, which are: 1) 14 BESt practices questions, 2) full assessment (175+ questions) and 3) on-site verification by a third party.

2.2.1.2. BOMA BESt Assessment Overview: BOMA Building Environmental Standards OFFICE Module (Revised August 2013)

The six (6) Assessment sections of the BOMA Office Module (BOMA, 2013b) are the same as the 2010 version, but the weightings are slightly different. The indoor environment section was increased from 17.5% to 18% while the 'Emissions and Effluents' has been reduced from 17.5% to 17.0% The beginning of the Indoor Environment section states that a comprehensive approach is necessary in considering an occupant's health and comfort. However, given Thermal Comfort, or ones satisfaction with the thermal environment, is the only form of comfort mentioned in the BOMA BESt Assessment Overview, and does not necessarily include other aspects of comfort, such as acceptable levels of other environmental stressors, this term and any conclusion based on it are very restrictive. Sample questions are also given, which include: are the building staff sufficiently trained to implement an IAQ program to address tenant concerns? This is an important question because if perception is a vital part of IAQ Assessment, either reactive or proactive, then if the building operator is not properly trained to effectively respond to occupants' IAQ concerns, it could make the IAQ problems worse due to the operator's lack of sensitivity or understanding of how to engage the occupants.

2.2.2. American National Standards Institute/American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ANSI/ASHRAE)

2.2.2.1. AHRAE History

As stated by Janssen (1999) in 'The History of Ventilation and Temperature Control', ASHRAE is an organization responsible for developing and publishing codes for the minimum requirements for heating and ventilation of buildings. Their work has resulted in a body of knowledge whose most up to date versions, at the time of this paper, are currently described in ANSI/AHRAE (2013b) 55 – 2013 for Thermal Comfort and ASHRAE (2013a) 62.1 – 2013 for Ventilation.

2.2.2.2. ANSI/AHRAE, Standard 55 – 2013: Thermal Environmental Condition for Human Occupancy (2013b)

The importance of the majority of occupants accepting the building's indoor air quality is clearly outlined in the purpose of ANSI/ASHRAE Standard 55-2013 (2013b). The purpose of Standard 55, as given in Section 1.0 is: 'to specify the combination of indoor space environment and personal factors that will produce thermal environmental conditions acceptable to 80% or more of the occupants within a space.' To further clarify this statement, it is important to look at the standards definitions of 'Environmental' and the 'Personal Factors' in Section 2.1. The Environmental Factors are defined as: temperature, thermal radiation, humidity, and air speed; whereas the Personal Factors are: activity and clothing. Table 5.2.1.2. (Appendix F) lists the metabolic rates for typical tasks, while Table 5.2.2.2A and B (Appendix G) details the insulation values for clothing and garments. Figure 5.3.1 and F.3.3.A (Appendix H) are graphical representations of the relationship for the determination of the Comfort Zone in the former and average air speed and operative temperature in the latter.

In the specific definition for Comfort, Thermal Comfort is an allowance for subjective input from the occupants. Nevertheless, the subjective input has been defined in terms of whether the occupants express satisfaction with the thermal input and not with anything else that might impact comfort in the environment. The authors are aware of this limitation and note in Section 2.4 of the Scope ANSI/ASHRAE Standard 55 – 2013 (2013a) does not address non-thermal indoor parameters, including, physical, chemical, or biological space contaminates that may affect the occupant's comfort or health. Therefore, if the IAQ investigator is not aware of this qualification, they would only measure the indoor environment's air temperature and if it is within the acceptable temperature range and the occupants state the temperature is acceptable, the investigator may conclude the occupants are comfortable. However, by doing this, other factors related to comfort would be overlooked.

2.2.2.3. ANSI/ASHRAE, 2013a, Standard 62.1 – 2013: Ventilation for Acceptable Indoor Air Quality (2013a)

The importance of the majority of occupants' accepting the building's IAQ is clearly outlined in the purpose of the Standard 62.1 – 2013 (ANSI/ASHRAE, 2013a). The purpose of Standard 62.1 is to specify minimum ventilation rates and other measures intended to provide Indoor Air Quality acceptable to human occupants and minimize adverse health effects. As previously mentioned, this standard also defines acceptable Indoor Air Quality as having no known containments at harmful concentrations where the majority (80% or more) of the occupants are satisfied.

Therefore, both ANSI/ASHRAE standards indicate the air is acceptable if only 20% of the people exposed to it find it unacceptable. As noted in the introduction of this thesis, due to personal variability in preference to comfort and other factors, it is impossible for the quality of the indoor air to be acceptable to 100% of the occupants. However, neither of these standards indicates how to manage the concerns of the other 20% of the occupants, nor even if such concerns are relevant. These topics will be examined in the Discussion Section of this thesis.

The Standard also gives instructions on what Indoor Air Quality entails and how it may be modified. Section 4 instructs the assessor to judge not only if the air immediately entering the building at the time of normal occupancy is acceptable but also to note if there might be environmental conditions in the surrounding that could possibly impact its quantity and quality in the future. With respect to the indoor air within the occupied areas, Procedure 6.1.2 advises the assessor to measure/observe both quantitative (analysis of containment sources and concentrations limits) and qualitative (level of perceived indoor air acceptability) factors when setting the outdoor air intake rates and other design parameters.

Along with defining various other parameters, the later part of the Standard discusses subjective evaluations for Indoor Air Quality Assessments. Section B5 addresses Subjective Evaluation of IAQ by noting the adequacy of control may rest upon subjective opinion. However, with the authors of this Standard not defining the word 'control' and how to assess it, it is hard to understand this sentence. The authors also mention the IAQ assessor should spend at least six (6) minutes in a space before determining if it is acceptable or not. While it appears these directions could mean the authors are giving credibility to the occupant's perception of IAQ, this is not correct; the text states the assessor is use their own perceptions as a surrogate for the occupants'. Due to this, the evaluation uses a quantitative and not qualitative subjective standard.

Even though such instructions may be incomplete and do not constitute a well-considered Indoor Air Quality Assessment Methodology, the standard does have important information, especially in terms of listing known contaminants. Table B-1, is a 'Comparison of Regulations' and 'Guidelines Pertinent to Indoor Environments' (Appendix I); Table B-2, are the 'Common air contaminants of concern in nonindustrial environments' (Appendix J) and Table B-3, lists the 'Concentrations of Interest for Selected Volatile Organic Compounds' (Appendix K).

Standard 62.1 – 2013 (ANSI/ASHRAE, 2013a) also stressed the importance of first clarifying the type of indoor environment being assessed so the appropriate standards and guidelines are applied. To this end, the types and levels of contaminants often found in industrial environments should not be applied to office spaces where the occupants do not wear personal protective equipment, and may not be as healthy as a typical worker in a commercial/industrial setting. In addition, the typical office workers interaction and response to their environment is most likely different to that of a typical commercial/industrial worker, something that may play upon the mental factors previously discussed by Runeson and Norback (2005).

2.2.2.4. ASHRAE Indoor Air Quality Guide, Best Practice for Design, Construction and Commissioning (2009)

ASHRAE (2009) produced a guide offering cost-effective recommendations to proactively improve IAQ for those designing, constructing and managing buildings. The introduction to the guide indicates the document has two (2) parts, each with supporting objectives: Part I is the 'Summary Guidance' (Appendix L) and Part II is the 'Detailed Guidance'. While all of the listed objectives in Part I are related to the health and comfort of the built environment, Objective 5: 'Limit Contaminants from Indoor Sources'; Objective 6: 'Capture and Exhaust Contaminants from Building Equipment Activities'; and Objective 7: 'Reduce Contaminant Concentration Through Ventilation, Filtration and Air Cleaning' are of particular importance in improving the Indoor Air Quality of pre-existing buildings. An example of this would be in Section 6.4, maintaining proper pressure relationship between spaces to contain contaminants. Spaces with contaminants such as excessive moisture or those containing unhealthy levels of airborne chemicals should be negatively pressurized to the surroundings areas, whereas occupied areas, containing office occupants who would not be wearing personal protective equipment to mitigate exposure, should be positively pressurized to the contaminated areas.

2.2.3. Federal-Provincial Advisory Committee on Environmental and Occupational Health¸ Indoor Air Quality in Office Buildings: A Technical Guide (1995)

Federal-Provincial Advisory Committee on Environmental and Occupational Health (1995) published a revised Indoor Air Quality in Office Buildings. This technical guide, which was a report of the Federal-Provincial Advisory Committee on Environmental and Occupational Health, was meant to offer assistance for those conducting complaint-driven IAQ investigations in office buildings. With respect to guiding information, Table 1 (Appendix M) describes 'Factors and Sources Affecting Indoor Air Quality and Comfort' and Table 2 (Appendix N) 'Odours as Problem Indicators in Office Buildings'. 'Commonly Encountered VOCs and Their Sources' are listed in Table 3 (Appendix O). Sources include: Paint (Acetone); Chlorinated solvents (carpet cleaners), and Terpenes (cleaning agents). In respect to microbial levels of airborne mould, while the authors of the guide did understand that, unlike chemicals, people's individual responses to microbial levels do not allow for the determination of strict quantitative values, they did propose ranges which indicated if an area had excessive levels of airborne mould, requiring future remediation.

2.2.4. Government of Alberta, Environmental Public Health Indoor Air Quality Manual, (2012)

The Government of Alberta (2012) published a comprehensive guide for IAQ assessments to be used by various Public Health Professionals. The manual is a general framework and menu of tools to provide guidance for Alberta Environmental Health professionals in their investigations and management of Indoor Air Quality Investigations. The appendix of the manual offers a wealth of standards. Standards/guidelines are given, or mentioned, for the following areas: Chemical Factors – gases; Chemical Factors – vapours; Airborne Particulates – size; Airborne Particulates – asbestos; Airborne Particulates – man-made fibres; Particulates – lead; Environmental Tobacco Smoke (ETS); Radon; Biological factors, Non-Bacteria: Mould, Mites, Cockroaches, Animal allergens (dog, cat, hanta virus, rodent); Bacteria; Pollen; Consumer Products; Office Equipment; and Outdoor Air Factors (Appendix P). The section entitled 'Built Environment', lists mechanical (referring to the associated ANSI/ASHRAE Standards) systems and physical factors as being able to impact IAQ, including: the air handling units/system, finishes, furniture, carpet, vinyl flooring, paints, and building materials. In this section, the manual provides a useful illustration of a typical HVAC system (Appendix Q).

2.2.5. Government of Alberta. Indoor Air Quality Toolkit, Employment and Immigration (2009)

Government of Alberta (August, 2009) published an Indoor Air Quality Toolkit for the Employment and Immigration Ministry. The goal of the toolkit was to help the building operator and related staff to understand the typical IAQ issues and to offer 'reasonable solutions' to the most common problems. In addition, the authors note IAQ can affect people differently based on individual sensitivities; and even though the most sensitive will be affected first, those with less sensitivity may also react if the exposure continues or increases. The document lists the common causes of IAQ as: indoor air contaminants including chemicals, cleaners, dust, moulds, fungi, odours, and vehicle exhaust emissions, as well as, insufficient outdoor air, poor air quality or poor air circulation. To be complete, the document states noise, thermal comfort (temperature), humidity and lighting may affect the perception of air quality. In Section 4: 'Standards and

Guidelines', the authors listed acceptable levels for temperature, humidity/moisture, and other parameters including carbon dioxide, carbon monoxide, vehicle exhaust (Appendix R).

2.2.6. Government of Alberta, Indoor Air Quality: Mould Indoor Environments Risk Assessment and Management Program Handbook, Alberta Infrastructure and Transportation (June 2006, Revised June 2007)

In June, 2006 (Revised June 2007) Alberta Infrastructure and Transportation, with the assistance of the Alberta Research Council, produced the IAQ Guidelines. The Building Environment Unit of Alberta Infrastructure primarily uses the IAQ standards listed in Appendix 3 (Appendix S) of this document to determine which compounds to measure and their acceptable levels. Amongst the listed parameters are: temperature, relative humidity, carbon dioxide, carbon monoxide, total dust, total volatile organic compounds, and others, which include asbestos, radon, lighting and airborne fungi. When the Building Environment Unit collects viable mould samples, the acceptable levels are based on information from the 'Federal-Provincial Advisory Committee on Environmental and Occupational Health (1995) Indoor Air Quality in Office Buildings: A Technical Guide'.

2.2.7. National Standards of Canada, Psychological Health and Safety in the Workplace – Prevention, Promotion, and Guidance (2013)

Due to numerous factors within the workplace that may affect the psychological condition of the worker, the National Standards of Canada (2013) published the 'Psychological Health and Safety in the Workplace – Prevention, Promotion, and Guidance'. With the previous citations indicating a link between environmental stressors and the individual's internal (qualitative) perception of Indoor Air Quality, this standard is also cited to highlight parts of it that may speak indirectly to IAQ in terms of how it defines health, safety and other related factors which can be changed to improve the perception of Indoor Air Quality.

One of the primary purposes of the Standard is the elimination of hazards in the workplace that may pose a risk of psychological harm to the worker/occupants. Part of the vision of the document is, 'actively works to prevent harm to worker psychological health', including 'negligent, reckless, or intentional ways, and promotes psychological well-being.' Psychological or Mental Health is defined as: 'a state of well-being in which the individual realizes his or her own abilities, can cope with normal stresses of life, can work productively and fruitfully, and is able to make a contribution to his or her community.' In addition, a Psychologically Healthy and Safe Workplace becomes: 'a workplace that promotes workers' psychological well-being and actively works to prevent harm to worker psychological health including in negligent, reckless, or intentional ways.'

From these various definitions comes the important phrase 'actively works to prevent harm'. This proactive term, which when combined with Section 4.3.4 concerning Identification, Assessment and Control of possible hazards in the occupants' environment would imply that by controlling such factors within the acceptable tolerance levels of the occupants, can promote psychological health. However, upon reviewing Subsection 4.3.4.2, there is no explicit statement concerning the physical environment, except indirectly. This apparent oversight could either imply the physical environment and those concepts related to it, such as Indoor Air Quality, are not believed to affect the worker's psychological health. Or, more likely, it is a factor that has been overlooked. Nevertheless, since the section heading states there are other factors which may be associated with psychological health, ones that can be actively modified to prevent present and future harm, it is then left to those who specialize in Indoor Air Quality Assessments to make the argument.

2.3. Methods of Applying IAQ Standards and Guidelines

This section discusses how the previous IAQ standards and guidelines can be applied to indoor environments. In respect to IAQ and those standards identifying which quantitative and qualitative parameters within a specific environment should be measured to determine if the selected environment meets the selected IAQ standard, an IAQ method outlines the systematic approach to be used to make these measurements. Depending on how detailed the methodology is, the IAQ method could include not only which parameters are to be measured, but also the reasoning behind the selection of the sampling areas. In addition, the method may also state where, when and how many samples are to be taken. Furthermore, for completeness, the methodology should address the limitations of the technique, and discuss the analysis and interpretation of the results.

2.3.1. BOMA BESt® Version 2, Application Guide (Revised August 2014)

BOMA does not specify how any of the Verification Assessments are to be conducted, providing only non-specific guidelines to the building operator. According to Step 6, Verification, the on-site visit will take approximately three (3) hours long, but may vary depending on the complexity of the building. Based on the personal experience of this researcher in the Building Environment Unit (BEU) during field research, IAQ assessments have taken between four (4) to nine (9) hours. The guide also states the assessor will review all relevant documentation, and 'interview the building management team, and conduct a walk-through of the property.' Depending on whether the operator had aforementioned materials available, BEU members were able to review pertinent documentation for cleaning and air filter changes. In a majority of the buildings, members of the BEU were also able to discuss and inspect the AHUs. Afterward, depending on the assessor, a number of walk-throughs were performed, followed by numerous IAQ Spot Tests throughout the building. The guide also mentioned that scoring of the questions can be adjusted depending on the outcome of the Verification.

2.3.2. BOMA BESt Assessment: Office Buildings (June 2009)

Building Owners and Managers Association of Canada (BOMA) (June 2009) for office buildings offered a number of questions to be directed at the operator regarding IAQ. Examples of questions from this document included: 5.1 – 'Ventilation', asks if the carbon dioxide levels are below 850 ppm; 5.2 – 'Filtration System', brings up the efficiency of the air filters; 5.3 – 'Humidification System', asks about what type of humidification system is used; 5. 5 – 'Parking and Receiving', asks if there are measures to prevent intake of exhaust fumes into the building from the loading dock; and 5.6 – 'Control of Pollutants at Source', queries if there are ongoing observations or complaints of mould or excessive water. Section 5.7 – 'IAQ Management', brings up the question of whether there are documented means of addressing tenant/occupant concerns regarding IAQ and determining if the building management is sufficiently trained to implement an Indoor Air Quality investigation, and if they are not, do they know to bring in a professional.

Although such questions are related to Indoor Air Quality, none of them ask whether the building operator has directly interacted with the occupants to gauge their satisfaction of the IAQ. Nevertheless, it could be inferred that since there should be documentation to enumerate and address the occupant's Indoor Air Quality concerns, this must mean the lower the number of complaints, the better the IAQ. However, if there is no means for an external party to proactively question or interview the building occupants, there is no way to know if the lack of IAQ complaints may be a by-product of the occupants not knowing how to log a concern, or they feel the operator will not act on their requests and have given up. Without requiring the operator to regularly engage the occupants in respect to their satisfaction of the IAQ, any number of assumptions could be made from indirect measurements. As such, these questions imply that since the building operator has not been instructed to discuss IAQ with the occupants until there is a complaint, the methodology is reactive.

2.3.3. Federal-Provincial Advisory Committee on Environmental and Occupational Health, Indoor Air Quality in Office Buildings: A Technical Guide (1995)

The need to be aware of differing reactions to environmental conditions is examined in this section of the guide. Although the authors realize the standards of comfort may vary from one individual to another, implying not everybody can be satisfied with the air quality, the authors still advocate taking all reasonable measures to make the necessary corrections so long-term resolution may be possible. In keeping with this practice, the authors mention, 'it is in the building manager's best interest to respond promptly and seriously to all complaints about indoor environment and to establish credibility through open communication with the building occupants.' The researchers of the technical guide stress that if this is not done, it may lead to frustration and anxiety in the occupant's which could magnify the issues.

Due to the complaint-driven nature of this process, the assessment begins as a fact-finding exercise, meant to link possible sources of pollutants to the symptoms. The initial walk-through helps to gain first-hand information to allow the investigators to devise a theory to link pollutants to symptoms, and make primarily recommendations. Other suggestions are to review the complainant areas, take preliminary measurement and airflow patterns to determine how the occupants may be exposed to substances that could be possibly related to the symptoms. If further information is needed, a detailed assessment, including the measurement of a wider range of parameters, would take place.

2.3.4. Government of Alberta, Environmental Public Health Indoor Air Quality Manual: A Guide for Environmental Public Health Professionals (2012)

Public Health investigations are also instigated by complaints concerning the quality of the indoor air. As part of the introduction to Indoor Air Quality Investigations, it is noted that due to the complexity of indoor air concerns, investigators often have difficulty associating specific physiological effects to specific contaminants. To manage such complexity, and to focus the investigation, the inspector is to determine if the source of the complaint is psychological, biological or physical and make the necessary rectifications if possible.

The manual suggests the question of perceived or real health effects requires careful assessment. Assessment is divided into three (3) phases. Phase 1 is the 'Initial Screening', which involves determining if the complaint falls under the public health mandate, and if so, it would continue onto Phase II which involves a telephone interview. The phone interview is used to gather information to form an initial hypothesis for the possible sources and causes of the complaint. If the concerns cannot be addressed over the phone, or there is insufficient information to develop a theory, then Phase III – 'Site Investigation' - would occur. When the Public Health Inspector is onsite, they are not only to interview the complainant, but also, if necessary, others, including all occupants, building manager and anybody else who may have knowledge of any circumstances related to the complaint.

This information along with environmental monitoring and questionnaires can be used to further develop a theory of the causative agents and possible solutions. The questionnaires include those for the Telephone Interview, Onsite Interview and walk-through. The questionnaires and a flow diagram of the process are shown in Appendix T.

2.3.5. Government of Alberta, Employment And Immigration, Indoor Air Quality Toolkit (2009)

The GOA Employment and Immigration Toolkit advocates measuring Indoor Air Quality information both proactively and reactively. As an ongoing means of monitoring IAQ, the toolkit suggests the building operator should routinely inspect the work area for potential issues or sources of contaminants, however, it does not state the occupants should be asked if they have any concerns about the air quality. Another proactive assessment is the formal Health Survey (Appendix U). According to this toolkit, the third way an IAQ assessment may begin is as a result of a complaint. Communication is listed as a vital part of the process, and is considered to be necessary in any complaint-driven investigation and requires occupants' feedback.

As described in the GOA Toolkit (2009) the reactive or complaint-driven IAQ assessment consists of three (3) steps. Fact-finding occurs at Step 1, and is used to gather information and documentation including floor plan and complaint forms. Step 2 is the walk-through of the building and inspecting various components of the air handling systems, and looking for possible causes of the complaint. The last step is talking to the occupants in the affected areas, taking time to listen to their concerns. The process is shown in the 'Assessment and Resolution Flow Chart' (Appendix V). At the bottom of the flowchart it is indicated that if the IAQ issues have not been resolved, the operator should consider hiring an IAQ consultant or HVAC specialist.

The Building Environment Unit of Alberta Infrastructure has often been contacted by OHS personnel or the building operator at this part of the assessment to assist in the IAQ investigation.

2.3.6. Government of Alberta, Alberta Infrastructure, Indoor Air Quality: Mould Indoor Environments Risk Assessment and Management Program Handbook (June 2006, Revised June 2007)

The GOA Indoor Air Quality Guide (June 2006, Revised June 2007) was developed by a panel of experts from the Alberta Government and private industry reviewing IAQ documents from North America and Europe. The guide recommends IAQ management programs are to be routinely conducted in Government of Alberta buildings through either a 'Preventative Maintenance Routine' or an 'IAQ Response Process'. Preventative Maintenance Routine is to occur regularly to ensure the building provides a healthy work environment to the occupants. As part of the preventative maintenance, there should be periodic proactive testing of the Comfort Factors. Appendix 3 of the document lists temperature, relative humidity, carbon dioxide and carbon monoxide as the Comfort Parameters. In comparison, the IAQ Response Process is complaint-driven. The guide stresses both the technical and health components are to be addressed; however, the word 'health' is not defined. Throughout the process, timely communication is required to build trust, and responses related to the investigation are to be reported back to the person who made the initial IAQ complaint

The IAQ Response Process consists of three (3) steps, each building on the previous information. Level I includes: a walk-through survey of the affected areas to gather information, conducting a physical inspection and then taking corrective actions if possible. At this level the occupants and other affected parties are interviewed and, if possible, the extent of the problem is defined. The investigation continues onto Level II if the problem persists, and involves measuring Comfort Parameters in the affected areas. Level I and II are to be conducted by the building operator if they have the necessary experience. If the IAQ issues cannot be resolved by the onsite personnel, the building operator is to obtain assistance from technical/professional resources with the necessary qualifications. Such persons include the Building Environment Unit of Alberta Infrastructure. The 'IAQ Response Process' and 'IAQ Walk-Through Checklist' are shown in Appendix W.

2.4. Overview of Cited IAQ Standards and Methods

Although the working definition of Indoor Air Quality offered at the beginning of the thesis appears inclusive to the point of being vague, the preceding information reflects how complex Indoor Air Quality can be. As a result, an argument can be made to define Indoor Air Quality as: '*A person's complete response to elements within an indoor environment which may cause them excessive stress, and which their perceptions may attribute to their personal acceptance of the indoor air*.'

In reply to this *ad hoc* definition, some would argue any attempt to adequately gauge not only one person's 'complete response' to the built environment, let alone an entire building, is far too complex an activity, one that should be left to the certainty of calibrated IAQ test equipment. This observation would be correct if the intent of the methodology was to acquire all such knowledge. It is not. Although there is uncertainty, it is believed the goal of a well-designed methodology is first to define the essential elements of an event (Thesis Objective), and then take the necessary measures to capture sufficient data to allow researchers to form a realistic picture of the event. For the current method, both relatively certain (quantitative) and relatively uncertain (qualitative) data is relevant, not only to highlight the major IAQ concerns of a building, but also what might be causing them (Methodology Objectives - Primary Goal).

Before proceeding, common themes expressed in the information cited in the Standards and Methods Sections will be highlighted. This summation will be used as a starting point for the formal development and description of the proactive, occupant-centered, mixed-methodology that could be implemented for conducting BOMA IAQ Assessments.

2.4.1. Standards/Guidelines:

1. There are a large number of natural or man-made substances in the built environment that can affect the Indoor Air Quality.

2. Some substances or facets of the environment can be easily measured, others cannot.

3. People have different perceptions of what is acceptable and what is not acceptable IAQ.

4. Although all of the IAQ Standards are based on symptoms, and are therefore, complaint-driven or reactive, such standards can be applied to proactive inspections.

5. Due to the lack of specific complaints or symptoms to narrow down which IAQs tests to perform, proactive IAQ assessments may require more testing (including their respective standards and guidelines) than reactive.

2.4.2. Methodology:

1. Indoor Air Quality Assessments are a form of Hazardous Assessment. It is data-gathering and hypothesis-generating process, involving multiple steps. These steps include: 1) reviewing and inspecting mechanical system's associated with ventilation and thermal control; 2) walking-through all areas of the structure which are part of the

assessment to look for sources of possible containments, their possible pathways and the occupants that may be exposed through these pathways. The third step is to link these elements together and then offer corrective actions to bring occupant exposure of the specified factors back to acceptable levels.

2. Both proactive and reactive assessments require the assessor to check how well the mechanical system is operating, as well as, the quantity and quality of the source air being drawn into the building.

3. The effectiveness of the IAQ Assessment depends not only on the equipment but the ability of the assessor who is performing the assessment. The quantitative assessment should be conducted by those who know what tests are to be conducted based on the site assessment and complainants' symptoms, as well as, how to use the IAQ equipment and the limitations of the equipment. The qualitative assessment should be conducted by those who are able to interact with the occupants in a non-judgmental fashion, and are capable of engaging the building occupants in an empathetic manner.

4. Whether a complaint-driven or proactive IAQ Assessment is being performed, open-communication with the occupants is important. Such input will not only improve the amount and quality of data the investigator has at their disposal to better understand the occupants' past and present perception, but also empower the occupants and build trust.

5. Questionnaires are a valuable source of data, but may limit the amount of information acquired from the occupants. IAQ Questionnaires may be used as an initial screening

tool to determine which occupants have IAQ concerns, but questionnaires should not be used afterwards when occupant engagement is required.

3.0. Preliminary Requirements for the BOMA IAQ Assessment Methodology

The preceding sections involve proposing a method to measure both the quantitative and qualitative aspects of the building environment. Before doing so, the topics of Standards/Guidelines and Methods are going to be discussed more critically. This will be done to challenge the basic assumptions often overlooked by those who conduct Indoor Air Quality Assessments. This is not undertaken to move the arguments beyond the scope of the thesis, but to give firmer basis to premises upon which the methodology is built. The discussion will begin by exploring the philosophical relationship between the assessor and the assessed.

From a philosophical perspective, the observer of an event attempts to identify and define the items which they believe the event consists of, and then, through trial and error, endeavours to determine if these observations are correct. Ontology is the attempt to define what actually exists, including the assumptions and beliefs they hold about reality. Biesta (2010) clarifies this term further,

> With regard to social and behavioural research one of the most important distinctions is that between what we might refer to as *mechanistic ontology* and a *social ontology*. Whereas the first would approach the world in deterministic terms, that is, a system in which there are causes and effects and deterministic connections between the two, the second would see the world as a world of meaning and interpretation.

For IAQ Assessments, it could be asked whether a standard or the subset of parameters within it and by which the level of quality is described, should be solely based on measureable and definable causes and effects. Or instead, should the quality of the air be defined by aspects inherently more uncertain? Epistemology asks not only if the knowledge or standard is correct, but how is it developed? For IAQ Assessments, this begs the question of how do you develop the standards or methodology? Epistemology brings up the question of independence, or level of interaction between the observer and the observed. An independent epistemology viewpoint would see the 'truth' or 'standard' being developed by the observer alone, while a dependent or interactive paradigm would see it achieved through communications with the observed (occupants).

3.1. Perspectives

In an attempt to answer these questions, various philosophical perspectives, or world views (Mayan, 2009) will be discussed, including Positivist, Constructivist and Pragmatist. Each has a different concept of what represents truth or a standard by which truth of a situation may be defined; and each has a different method of developing, comparing and validating the truth.

3.1.1. Positivist

Basing knowledge on what is solely experienced by the observer through their senses is a fundamental aspect of Positivism. Hume (2007) proposed all knowledge results from observations and the linear process of cause and effect, a philosophy consistent with the Mechanistic Ontology. Objectivity must be maintained so well-considered inferences can be formed from the observer's observations. Comte (1957) takes this further and defines truth in empirical terms. Therefore, if an empirical standard has been set in one situation, it should be employed in similar circumstances if objects within it are believed to be the same.

To Comte (1957), this idea also extends to natural phenomena, including the actions and thoughts of people. Comte believed people strictly obeyed a set of specific and definable rules as closely as objects obey Newton's 'Laws of Motion'. This viewpoint is evident in the following quote, 'The phenomena of human life, though more modifiable than any others, are yet equally subject to invariable laws; laws which form the principal objects of Positive speculation.' For IAQ Assessments, this would suggest the true IAQ Standard can be defined (Mechanistic Ontology) and set through external observations (Independent Epistemology), and such a standard can be applied to all similar physical environments and individuals within them. Therefore, this philosophy implies one (1) set of IAQ Assessments Standards should be applied to similar indoor environments, regardless of the type of people occupying the structure.

3.1.2. Constructivist

In comparison, Constructivism asserts truth is not an unmoving obelisk and is instead the result of the interaction between the observer, and the observed. Piaget (1950) theorized that while the cognitive philosophy of Constructivism agrees experiences are based on information acquired through our senses, our own recent and past considerations of what we have experienced also colour our perceptions. Therefore, each person comes to his own unique understanding of the world, which can differ from the understanding of others. Constructivism is the process of developing 'mental models' to explain what we experience. Thinking and its by-products are independent variables that may be invisible to the outside world. In this way, and by extension, learning takes place whenever we adjust our existing mental models to incorporate new experiences. This philosophy is consistent with the Social Ontology and has an Interactive Epistemology.

In respect to Indoor Air Quality Assessments, Constructivism disputes the stationary or absolute ideas offered by Positivism. Not only is there an important relationship between the observer and the observed, there is also one between the observed and the built environment. Due to both of these important and dynamic interactions, many different standards may be warranted, each of which can be unique to each and every occupant. For example, if Person X is in building X, the ambient conditions may lead them to perceive the IAQ as being acceptable, however if Person X is moved to building Y, and there is a part of the ambient conditions which is not measured, but can affect still them, they may find the IAQ conditions unacceptable. To further frustrate the process, there is also the chance two (2) people in the same area of the same building find the IAQ both acceptable and unacceptable. Therefore, by only relying on external standards for the acceptability of the IAQ, the assessment would be incomplete.

To some, this type of argument can quickly turn into an absurdity. If the premise is accepted that everybody might have a unique perception of the environment, and this might cause them to have a unique set of IAQ standards, then how it is possible to meet all of these standards? If there are 100 people in the building, there may be 100 standards. This could be asserted if the goal of the assessment was to meet everybody's standards. It is not. The proposed goal of the methodology is to be sufficiently comprehensive so as to acquire all pertinent data on the day of the assessments so it can be analyzed. If during analysis a number of cogent themes resolve themselves, showing a discernable association with aspects of the physical environment, then the building operator can determine what reasonable actions can be taken to improve overall indoor air quality.

3.1.3. Pragmatism

The philosophy of Pragmatism attempts to manage such inherent uncertainty in truth by accepting the lack of an absolute standard. Instead of viewing the world as being either completely certain (Mechanistic Ontology) or uncertain (Social Ontology), the philosophy of Pragmatism accepts both concepts can co-exist in one phenomenon. Dewey (1929) rejected the dualistic approach of modern philosophy, where mind and matter or viewer and viewed are considered independent, in favour of a naturalistic paradigm viewing knowledge as arising from an active adaptation of the human organism to its environment. In other words, even if we are aware and accept a person's experiences does not reflect absolute truth, either because of the inherent weakness of our senses or perceptions may eschew our judgement, we can still acknowledge these imperfection and produce standards which best capture various levels of uncertainty as best as we can. In the context of Indoor air Quality, Pragmatism accepts the validity and necessity of both quantitative and qualitative standards.

Therefore, the Pragmatic World View is offered as the best guiding principle to adopt in developing (Interactive Epistemology) an IAQ Assessment methodology that accept divergent standards (Mechanistic and Social Ontologies). Pragmatism does not acknowledge that an absolute truth can be found. It accepts the perceived limitations and uncertainty of the objects within a system, and strives to figure out the best solution given these perceived limitations. Any methodology which strives to conduct an effective health assessment of an indoor space, be it for complaint-driven or proactive testing related to IAQ, needs to encompass both standards, in the realization that neither standard is more correct or important than the other. What is more important to acknowledge, is that both standards give a more comprehensive view of the Indoor Air Quality, as such, they should be viewed as complimentary, and not as adversarial. By accepting the fluid state of such a system, and all of the interactions likely to comprise it, it will better allow the assessor to pin-point the most important parameters and measure them.

3.2. Epidemiological Study Designs

A methodology does not only have to consider which standards are to be measured against, but also the time frame in which the study acquires data. Aschengrau and Seage (2014) describe the three (3) most common study designs: Cohort, case-control and cross-sectional. A cohort study design follows a group of people after they have been exposed to an event or substance to determine if such exposure resulted in any disease or reaction. The case-control study design first defines the effects, then attempts to link it to previous exposures. Both designs follow a group of individuals in time, whereas in a cross-sectional study design the causes and effects are measured at the same time. Based on these descriptions, all three (3) designs can show association, but the cross-sectional study design cannot suggest causation because it is not possible to show a specific effect is preceded by a specific cause.

As a result of this information and the ability to suggest causation, it appears the BOMA IAQ Assessment study design should be either cohort or case-control. If it is assumed the purpose of the present study design is to determine causation as well as association, then it is only logical to believe a design which may link cause to effect is preferential. However, there are a number of problems with such a conclusion. To begin, the amount of resources required to conduct an ongoing IAQ study would be more than many organizations, including the Government of Alberta, can devote, especially if the number of people and locations being monitored within a building is substantial. Furthermore, if the people with IAQ concerns have been in the building for a long period of time, and the building and general environment is in a relatively stable state of flux, with many previous factors leading to many previous IAQ concerns, having a study that collects additional information, is not necessary. And while a case-control study could, in theory, link present Indoor Air Quality symptoms to past events, most buildings do not have the necessary records or documentation that would make such studies feasible.

By judging against the need and resources available, the cross-sectional study design can best meet the needs and the requirements of an IAQ Assessment as long as its limitations are observed. First, the cross-sectional study design considers associations and not causation. Hill (1965) stated one of the fundamental requirements for studying and inferring causation is for the cause to occur before the result. Since the 'causes' and the 'effects' are measured at the same time in a cross-sectional study design, this basic requirement of causation cannot be met. Therefore, researchers using the proposed methodology can state if two (2) or more events occurred at the same time, and due to this, are associated with each other, but the researchers cannot state with any confidence if one event caused the other to occur. In addition, since the cross-sectional study design only acquires data on one day, such a narrow time frame may not gather input from occupants who are either away on holidays, off site, or sick; unlike cohort and case-control studies which have a wider time frame. Nevertheless , by not only taking a number of quantitative measurements throughout the building, but also interacting with the occupants and the building operator in respect to their shared history within the building, including who may be absent due to the Indoor Air Quality related-absenteeism, it may be possible to extrapolate - through inductive reasoning - the causes of such absenteeism.

3.3. Field Experience

While conducting onsite BOMA IAQ Assessments this researcher as a member of the Building Environment Unit had a number of field experiences. Most observations were written in the issued BOMA IAQ Assessments reports; however some observations could not be documented in the reports because they were unprovable, inappropriate or prone to conjecture. Nevertheless, due to their possible impact on this methodology they should be carefully mentioned. Primary amongst them was a perception that some of the office occupants believed the building operators would not follow through on most of the recommendations in the final BOMA IAQ Assessment Report. Whereas the three (3) types of assessments discussed in Section 1 are intended to measure environmental conditions and compare them to a standard (discussed in Section 2) so that recommendations can be made to improve the indoor environment, it is certainly possible the operator at the time of the request may not intend to follow through with some of the recommendations. This is mentioned because such a possibility can not only affect the effectiveness of this method, it can, as will be discussed in Section 5, create conflict which may increase the perception of IAQ concerns amongst the building's occupants.

3.4. Proposed Cross-Sectional, Convergent-Parallel, Mixed-Method Study Design

Before proposing a specific mixed-methodology to conduct BOMA IAQ Assessments, and then detailing its individual components, it is first necessary to clearly describe the basic aspects of a mixed-method design. Greene et al. (1989) indicate a mixed-method study design includes both the collection of quantitative and qualitative data. The former includes the collection of numbers from externally measured events, while the latter is designed to collect words. The researchers also note the method is not inherently linked to any particular inquiry paradigm. In addition, their work implies both streams of information are equally important, with neither taking precedent over the other. Given this description, the mixed-method study design follows the Pragmatic collection methodology of inclusivity and equality in the treatment of the acquired information.

In respect to a specific mixed-method study design which best meets the thesis's objectives, one that simultaneously measures both methods to acquire data and then comparing them, Creswell and Clark (2011) refers to it as a convergent-parallel study design. The researchers stated this design can be used when the 'researcher wants to triangulate the methods by directly comparing and contrasting quantitative statistical results with qualitative findings for corroboration and validation purposes.' This information is in agreement with the purposes of a BOMA IAQ Assessment. In Figure 3.3 of Creswell and Clark's book (2011) (Appendix X) is a flowchart representing this design. Step 1 involves designing and collecting the two (2) different data streams. Step 2 is the analyses of both sets, and Step 3 is merging them. The last step is the interpretation of the merged results.

While Creswell and Clark (2011) use the term convergence to imply the data streams are merged, it does not necessarily mean the two (2) groups of data are in agreement. Ostlund et al. (2011) discusses the triangulation triangle metaphor cited by Creswell and Clark (2011) to illustrate two (2) possible outcomes of comparing the quantitative and qualitative empirical data. In Figure 7 (Erberger and Kelle, 2003), the empirical data is in agreement or complementary. This is referred to as convergence. In comparison, as shown in Figure 8 (Erberger and Kelle, 20013), when the findings from the quantitative and qualitative groups of data are not in agreement, divergence occurs. Therefore, a convergent-parallel study design may have convergent or divergent results. To reduce confusion, when this thesis uses the word convergence it will be in reference to the merging/comparing of quantitative and qualitative data from a single sample location, and does not imply the two (2) streams are in agreement.

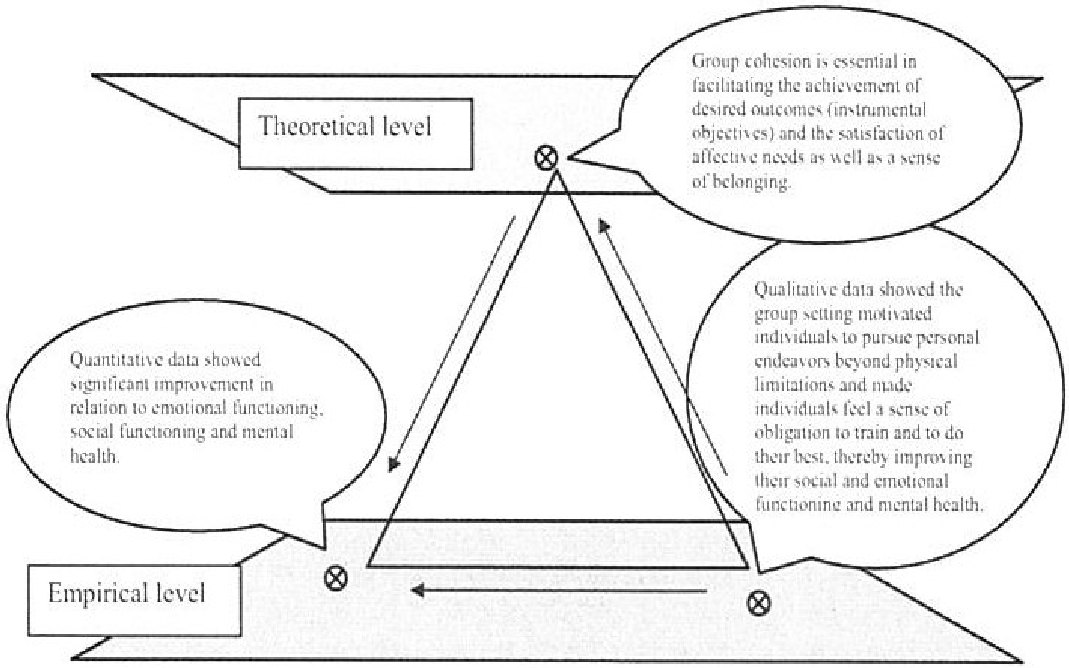


Figure 7 - Triangulation Triangle, Convergent Finding (Erzberger and Kelle, 2003).

Another clarification for the mixed-methods study design is in respect to data collection. As noted by Creswell and Clark (2011) there are four (4) questions that need to be asked and answered in respect to decisions and recommendations for the collection of quantitative and qualitative data: 1) Will the two (2) samples include different or the same individuals? 2) Will the samples be of the same size? 3) Will the same concept be assessed quantitatively and qualitatively? 4) Will the data be collected by two (2) independent sources or by a single source? The answers to Question 1 and 3 are as follows: the intent of the methodology is to sample both quantitative and qualitative IAQ data from each occupant in each of the sample locations. To answer Question 2, ideally the two (2) sample sizes should be the same so individual comparisons can be made, however, as it was the experience of this researcher in the BEU during PHASE I and PHASE II BOMA IAQ Assessments, intervening events did not always allow this to occur.

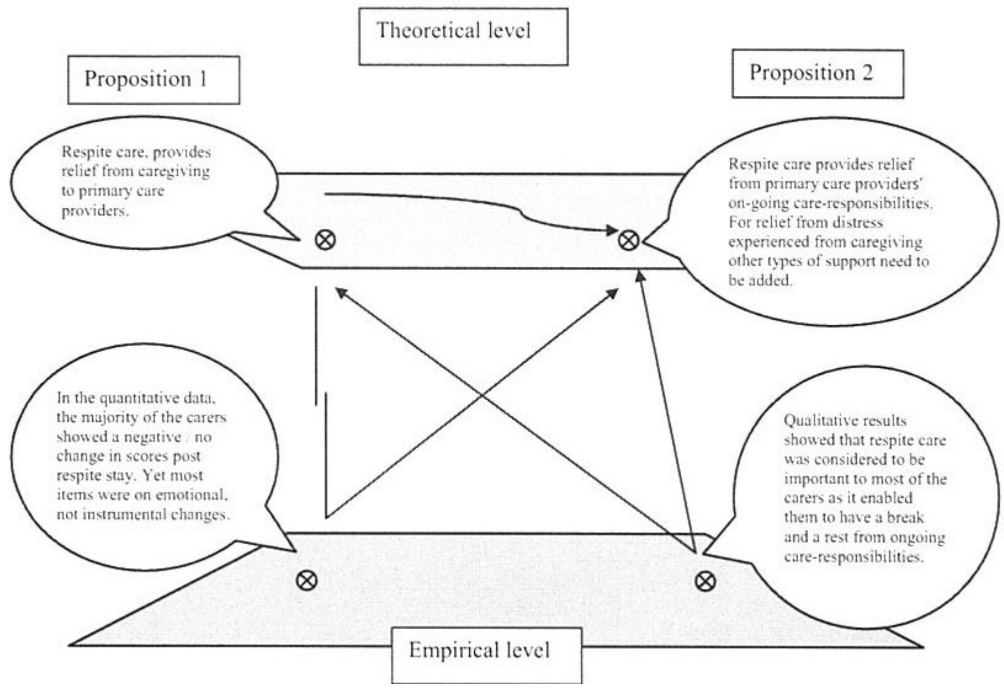


Figure 8 - Triangulation Triangle, Divergent Findings (Erzberger and Kelle, 2003).

In respect to Question 4, which Creswell and Clark (2011) clarify as being a question of how many forms are used to collect the data, the BEU has been collecting both the quantitative and qualitative data on one (1) form. As will be discussed in Section 5, the majority of the Building Environment Unit BOMA IAQ Assessments have been conducted by one (1) staff. With this limitation, and with the cross-sectional study design requirement to conduct the testing on one (1) day, it has not been feasible for the assessor to use more than one (1) form. However, if staffing was not a limitation, having two (2) people to gather the information would be more efficient and effective; with one (1) person only acquiring the quantitative data and the other only the qualitative data. As to which data set is measured first, it has been the experience of the researcher that while it is a common practice to take quantitative measurements first, the occupants often begin to discuss their concerns at this time. Due to this, data collection of both streams of data often occurs simultaneously if one (1) staff is assessing.

Although the cited information paints a promising picture, Creswell and Clark (2011) also seem to imply the convergent-parallel study design has more weaknesses than strengths. The chief strength cited for the convergent-parallel study design is its inherently efficient because both data sets can be simultaneously acquired and analysed using traditional methods normally associated with each data set. This allows the work to be divided amongst teams, thereby reducing the time spent on field work. Weaknesses include the need for members acquiring the data to have expertise in either quantitative or qualitative research or, if the efficiency is to be optimized, one (1) team would have to be composed of those with the necessary proficiency in both fields. There are also the problems of what to do if the data sets consist of different sizes and also, what do to if the quantitative and qualitative information contradict each other when they are merged?

Along with the apparent imbalance of strengths to weaknesses, there are a number of objections given against mixed-method research in general, which may if not addressed, undermine any of its conclusions. Mayan (2009) commented on six (6) areas which some researchers cite to dismiss the importance of qualitative data, and by extension, mixed-method study designs. Of these, Objection 3 – It's Biased, Objection 4 – It's Not Empirical Research and Objection 6 – It's Irrelevant, appear to be the strongest arguments against qualitative research.

For Objection 3, Mayan (2009) does not argue the data is biased because it should be. Qualitative data is not supposed to be randomized, where each point of data has an equal chance of being chosen. Mayan stated the goal of the qualitative researcher is to measure as much variety of experiences within the phenomenon, allowing the researchers to describe the experience more fully. It must be remembered that quantitative and qualitative standards are fundamentally different. While the same IAQ quantitative standard can be applied throughout a building because the systems being assessed were designed to produce a specific result which can be measured, in contrast, individual IAQ qualitative standards as they relate to the internal perceptions of a person's sensory experiences, are much less likely to be the same because each is unique to the person who experiences them.

In Mayan's (2009) counter argument to Objection 4, she replies, as does Webster's Online Dictionary (2015), any information acquired through the senses and not through theory is inherently empirical. As such, by definition, any observations, either with a calibrated instrument or experienced through a person's senses, are empirical. The issue then may be if there are multiple assessors, each with their own standards, such compounded uncertainties would conflate the data. Unlike different people using the same measuring device to record quantitative data from the environment, different people observing or obtaining data during an interview, are likely to take away different information from the same experience. Since it is unlikely for different assessors to interview occupants using the same personal standards it is then only possible to reduce the variability between the qualitative data acquired from different occupants by having the same assessor conducting all of the interviews, especially if the means of acquisition is dependent on the assessor's style of engagement. This implies that although the one (1) interviewer's personal engagement style may affect the data, if they try to be aware of their own bias, all the qualitative data could be equally affected.

Objection 6 questions the relevance of qualitative data. Previously, it was mentioned IAQ Research was originally initiated in response to occupant's comfort and safety concerns that were believed to be related to the indoor conditions (Janssen, 1999). This prompted ASHRAE to choose and measure certain parameters within the indoor environment as indicators of the quality of the indoor air based on the occupants' perceptions. This information was amassed and then averaged. Due to this, it appears that those who question the relevancy of qualitative data, as stated by Sandelowski and Barroso (2003), takes place because those who object forget where the data came from. As such, given the history of how the IAQ Guidelines were determined, it is therefore not logical to conclude, as Objection 6 does, that qualitative data is less relevant or real than quantitative data.

Based on the cited information in this and the previous sections, the importance and relevance of both quantitative and qualitative data in an IAQ Methodology has been established. Both streams of data are equally representative of the conditions within the building that can affect the quality of the air within the built environment. The remainder of the thesis will describe in detail both the quantitative and qualitative standards and methods of the proposed mixed-method study design. This information will include not only when the samples should be taken, but how the sample locations are chosen and how the information within each location is acquired. The sections will also list the strengths and weaknesses of the proposed methodology.

4.0. Description and Evaluation of Components

4.1. Quantitative Standards/Methodologies

4.1.1. Outdoor Air Quality

Whether a building has mechanical or natural ventilation, its sole source of fresh air is from the outside. To this end, the assessor should begin the assessment of the building's IAQ by observing[2] for any unusual odours in the outside air or other conditions that might affect the quantity or quality of the air being brought into the building. The assessor should keep in mind that although the building's mechanical systems can humidify, heat/cool and clean the air, there are many airborne gases, such as methane and carbon monoxide, which the mechanical systems are not designed to remove. This would also call into question if there are any vehicles or pieces of gas-powered equipment operating by the air intake such as: cars, delivery trucks, lawn movers and snow blowers. In addition, the assessor should observe if anybody is smoking by the intake or whether the outdoor air being drawn into the building is very warm or very cold. These conditions may tax the building's ability to keep the internal air temperature within the acceptable temperature range.

4.1.2. Building Operator

The next variables concern the building operator and their ability to adequately control and maintain the building's mechanical systems. Along with the building's ventilation and heating

[2] If the observer can maintain an unbiased and objective viewpoint and are aware of any confounding factors, their sensory observations can be considered to be valid and reliable quantitative data.

systems being properly designed and built so they adhere to the designated ANSI/ASHRAE standards, these systems have to be operated and maintained within the intended specifications. The building operator's ability to do this will depend on a number of factors an assessor could note during the assessment. Such information may include: What training does the building operator have? How many other buildings does the building operator take care of? How many years of experience does the building operator have in total as well as in the buildings they are presently are in charge of? In addition, it could be asked what training the building operator has in conducting Indoor Air Quality investigations.

4.1.3. Review Documents

Past and present documents related to the Indoor Air Quality should also be reviewed by the assessor. Prior to arriving at the building site to conduct the IAQ BOMA Assessment, the assessor will need to review the Building and Land Inventory Management System/ Risk Evaluation/Corrective Action Program (BLIMS/ReCAPP) Reports. These reports give an overview of the Government of Alberta building's various systems, and are conducted and written by a consultant. Questions and concerns from this report can be directed toward the building operator onsite by the assessor while the mechanical systems are being reviewed. The assessor can also inquire if the building's systems are operating within normal building parameters. This is important to know so that if there are any deficiencies in the parameters being measured, the assessor may use this knowledge to relate them to any deviations from the defined standards.

The building operator should also be asked if they are aware of any current IAQ issues expressed by the occupants. According to the Government of Alberta (2007) Master Specifications, Section 01050, the formal process by which GOA staff inform the building operator of an Indoor Air Quality Issue or any other concerns is through the Work Order Request Tracking System (WORTS) Reports. The assessor should not assume there is a linear relationship between the amount of WORTS Documentation the operator has and the occupants' satisfaction with the building's Indoor Air Quality. For example, if the operator is often in the building, the occupants may normally express their IAQ concerns directly to the operator who then resolves the issue, thereby circumventing the need to issue a WORTS. Another possibility is the occupants have issued many WORTS in the past, but the building operator has seldom responded, resulting in the occupants learning not to write any new requests. Either possibility has equal validity until the assessor interacts with the occupants to develop a working theory.

4.1.4. Mechanical Room(s) - Condition of Air Handling Units (AHUs)

The condition of the air handling units (AHUs) should be viewed with the building operator present so that they can describe the system and answer any questions. Based on this researcher's experience in the BEU one begins by asking the operator to verify which AHUs provide supply air for which parts of the building, followed by looking for the location and condition of the air intakes for each of the AHUs. The air intakes are the first parts of the AHU through which the outside air is brought into the building. The assessor will then observe if the air dampers, the components of the AHU which control the amount of fresh air entering the system, are sufficiently open to allow the minimal amount[3] of fresh air into the building. In some

[3] AI - TSB, Senior Mechanical Engineer with the TSB informed the Researcher (personal communications, April 14, 2015) that although it is not stated in the ANSI/ASHRAE Standard 62.1, air dampers should be open at least 10%.

cases, when the outside air temperature is either very warm or very cold the dampers may be entirely closed to save energy. When this occurs, it will greatly increase the volume of return air in the building and may increase carbon dioxide levels as well as other airborne contaminants.

After this, the various chambers of the air handling unit are to be inspected for debris, cleanliness and condition of the components (including fans and fan belts). Next, the pre and post air filters will be inspected to determine if they are adequately removing airborne materials. The building operator should be asked how often the air filters are changed, and when they were last changed. Other observations would include how dirty the air filters are and whether there is any air-bypass around the air filters? If the AHU has a humidification system, the level of relative humidity the system is set at can be documented and compared against onsite readings and perceptions. The assessor should also observe if there is any standing water in the humidification tray which could lead to excessive mould/bacterial growth.

To safely and thoroughly inspect these components, it is the common practice of the Building Environment Unit to ask the building operator to temporarily turn off the air handling system. If the system is on, the pressurization, noise and moving parts within the AHU may interfere with the assessor's senses and cause unsafe conditions. For this reason, this part of the inspection should occur before the building occupants arrive. Due to this, this part of the assessment has to be performed in a relatively short period of time, because if the system is down for an extended period of time it can, in itself, affect the building's Indoor Air Quality.

4.1.5. Occupied Areas

After observing or measuring parameters outside and within the Mechanical Room, the assessor will progress into the occupied areas of the building to begin sampling. Once the sampling locations have been chosen as per the proposed study design, readings will be taken with either calibrated IAQ equipment or by the senses of the assessor. The measurements will include: Comfort Parameters; levels of dust; cleanliness of work surfaces; visual assessment of supply and return airflow with a smoke pencil; visual assessment of pressurization between area separations (walls/doorways) with a smoke pencil. The level of formaldehyde and ozone within these areas should be measured if the assessor subjectively detects such odours, as well as, any other observations that may be related to Indoor Air Quality are to be noted.

All measurements are to be taken where the occupants spend the majority of their time inside the building. If not informed otherwise by the building operator or the occupants, it is reasonable for the assessor to assume the average Government of Alberta office worker spends the majority of their work day at their desks. Photocopying and storage areas should also be tested. Data should be acquired within the occupant's breathing zone. The Building Environment Unit of Alberta Infrastructure compares these readings against Appendix 3 of the Indoor Air Quality Guidelines (Appendix S), and measures only the Comfort Parameters in the morning and afternoon because they, unlike the other parameters, often vary greatly over the course of the day. All readings are to be taken with the occupants present so best to determine what the occupants are exposed to and how their own respiration may impact the IAQ. If the assessor believes the equipment is faculty or the readings are not representative, it is to be noted in the Final Report.

4.1.5.1. Comfort Parameters

Comfort Parameters include temperature, relative humidity, carbon dioxide and monoxide levels. Not only is the assessor to measure the air temperature, but they are to compare it against the area's 'set' and 'reading' thermostat temperatures. It should be noted if the area has a thermostat, and if it does, is it readily visible to the occupants and can it be adjusted as needed. The assessor should also note whether changing the set temperature of the thermostat varies the amount of air coming out of the air supply vents or whether it activates the areas perimeter radiators in the colder months.

While recording the Comfort Parameters, the assessor is to be aware of certain observations unique to each parameter. In Government of Alberta buildings, it is uncommon for there to be relative humidity adjustment switches or readouts. Due to this, and in buildings with humidification systems, the recorded relative humidity is to be compared against the set value for the particular air handling unit supplying the area of the building. Since carbon dioxide is produced by normal respiration, the number of people present (including the assessor) during the testing is to be recorded, as well as, factors which may modify it. To this extent, the assessor is to observe or ask: What is the normal number of people in the area? Is the area open? And if it is a room, were the doors entering it open or closed during the testing? And what is the normal level of activity in the area is, and did it occur during the assessment period?

Due to the inherent properties and dangers of carbon monoxide, special care is to be taken by the assessor in its measurement. As stated in the Government of Canada (2013), OSH Answers Fact Sheet for Carbon Monoxide (Appendix Y), Carbon Monoxide is a colorless and odourless gas that strongly binds with haemoglobin. By this action, it inhibits the ability of blood to carry oxygen and may lead to affixation and death. When the assessor is taking measurements, they should be especially aware of any possible sources of carbon monoxide inside and outside of the building. Furthermore, if the carbon monoxide readings remain above the acceptable limits (5 parts per million) the building operator or other person in care and control of the building should be immediately informed to discuss if further actions are required. If the carbon monoxide levels are above the Health Canada Residential IAQ Guidelines Levels for 1 hour (25 ppm) (Appendix P), then the affected areas may have to be immediately evacuated by the building operator or other person in care and control of the area.

4.1.5.2. Dust

The levels of measured dust within the building can be used to infer the efficiency of the air filters, as well as, the adequacy of the housekeeping. Dust can be present in a building either from the supply air, air pressurization between areas or from activities and objects within the space. The dust may be inhaled and cause the person to react. Levels of dust are to be measured in the ambient air, as well as, in the carpet and cloth chair[4]. High levels of ambient dust may indicate the AHU's air filters are not working properly, while entrained dust on the carpets and within the chairs may indicate the housekeeping is not adequate. Levels of dust are to be observed on work surfaces, including those above four (4) feet (high dust) which are commonly missed by the cleaning staff. The assessor is to determine if the dust levels are at or above moderate levels. This testing is often performed by running a finger over the horizontal work surfaces to see if dust begins to build up against the finger.

4.1.5.3. Supply Airflow and Air Pressurization

If the assessor has the time, skill and equipment, they may use a calibrated instrument to measure supply and return airflow, as well as, air pressurization. By doing this, the assessor can record the

[4] Whereas the acceptable level of ambient dust is 0.100 milligrams per cubic meter of air or less as stated in GOA, June 2006 (Revised June 2007), guideline (Appendix Q) the acceptable levels of entrained chair and carpet dust, being 0.80 milligrams per cubic meter of air or less, is based on research conducted by the manager of the Building Environment Unit, Colin Wildgrube.

amount of airflow and pressurization and compare such values against the ANSI/ASHRAE Standards. However, if the assessor does not have the necessary resources or skill at their disposal to take quantitative measurements, airflow and pressurization can still be subjectively measured with a smoke pencil. By holding the smoke pencil adjacent to a supply or return air vent, the amount of flow can be estimated. This will allow the assessor to not only judge the amount of airflow, but if there is short-circuiting between the supply and return vents. Ventilation short-circuiting occurs when air from the supply is drawn back too quickly into the return before it can adequately circulate in the room. A similar process can also be carried out for air pressurization by holding the smoke pencil at door entrances. This allows the assessor to visually observe if areas with contaminates are negatively pressurized to surrounding areas, and occupied areas are positively pressurized to surrounding areas.

4.1.5.4. Formaldehyde, Ozone, Total Volatile Organic Compounds (TVOC) and Other Observations

Finishes, furniture and other man-made articles present within a built environment can produce and emit a number of airborne chemicals which can affect the Indoor Air Quality. As stated by the Government of Alberta (2012) Environmental Public Health Indoor Air Quality Manual (Appendix P), formaldehyde, ozone and various types of Volatile Organic Compounds are often present in the indoor environment. Due to off-gassing from recent renovations or additions, including painting, new carpet and new furniture, high levels of airborne formaldehyde can be present for extended periods of time. If these or related activities have recently occurred, or the assessor senses these types of odours are in the test area, they should undertake specific testing for them. Ozone should be measured in areas where there are high levels of observed or suspected electrical activity. With respect to TVOC, since there are a number of volatile chemicals that cannot be sensed but can still affect the occupants, all test areas should be tested for their presence. Other observations that may be pertinent to IAQ can include signs of water-staining or discolorations which are indicative of excessive mould growth or the presence of items such as pieces of furniture or high cubicle walls which can block supply or return airflow.

4.2. Qualitative Standards/Methodologies

4.2.1. Qualitative Descriptive

Qualitative Descriptive (QD) is a naturalistic approach of interacting and acquiring first-hand information from the test subjects during an interview. Neergaard et al. (2009) stated QD is different from the other qualitative methods in a number of ways. The description is not as extensive as Ethnography. In addition, there is no effort by the researcher to develop a theory as in Grounded Theory and the researchers do not attempt to give an interpretation of the meaning of an experience as per Phenomenology. Instead, the primary goal of Qualitative Descriptive is to give an accurate and full description of an experience or event.

4.2.2. Assessor Engagement

As previously discussed, many so-called qualitative IAQ studies use questionnaires. The belief is that they adequately capture the occupant’s perception of the Indoor Air Quality. However, questionnaires by their nature are not only restrictive, but also create little engagement between the assessor and the occupants. In addition, if, as it will be suggested by the current methodology, the information from the occupants should be used to choose the most appropriate test locations, a questionnaire may not be able to acquire this data in a timely fashion.

Qualitative Descriptive information from the occupants should be acquired through one-on-one onsite interviews. To provide the necessary level of engagement, there are a number of abilities the assessor should possess. To maintain the naturalistic approach, the interviewer is to introduce a low level of interference to the interaction as possible, doing so by being non-judgmental and employing open-ended questions. If the assessor is capable of these traits, they should in theory adjust for some of the weaknesses apparent in qualitative testing. Sandelowski (2000) stated that by maintaining a naturalistic approach, it will increase the likelihood the obtained information will have both Descriptive and Interpretative Validity. Descriptive Validity occurs when an accurate enough accounting of the observed events is obtained so that most people observing the same event would agree is an accurate description of the event. Interpretative Validity occurs when the researcher gives an accurate account of the meanings of what the participants actually meant to attribute to these events. In either form of validity, the researcher is to be aware of their own ability to bias the information they acquire from the occupants.

Such requirements, and those personal characteristics required to conduct them, imply the assessor requires empathy. Svenaeus (2015) stated empathy is not to be confused with sympathy. To be empathic is to have awareness of other people's experiences, perceptions and personal reactions, while sympathy is endeavouring to experience the other person's perceptions and personal reactions. By being empathic, the assessor is better able to understand the occupant's personal standards and the situation by which their perceptions of the IAQ may have grown, without necessarily agreeing with them. If the assessor becomes sympathetic, their reaction will become biased. Therefore, a researcher can be objective if they have an empathic relationship with the occupants of a building, but the researcher cannot be objective if they are having a sympathetic interaction with the occupants.

Mayan (2009) described three (3) stages of the interview. The first step, or beginning, involves the interviewer introducing themselves to the participant and putting them at ease. For an IAQ BOMA Assessment, this would occur during the initial walk-through. Here the assessor would introduce themselves and remind the occupants a BOMA Assessment of the Indoor Air Quality is occurring, and it is a proactive assessment, and as such, is not based on any IAQ complaints. After the introduction which will give those present an overview of what type of tests will be performed and how long it may take, the assessor will inform the occupants that they will be back during the second walk-through if their area has been chosen to be tested.

If the assessor returns to the location, the formal stage or second stage of the interview starts. During this time, the assessor will be empathic and use active listening skills. Although the assessor will leave after this to determine if more test locations based on information from the interview, or to start taking measurements, the interview will continue whenever the assessor interacts with the occupants throughout the day. Departure, which is considered the last stage, takes place when the assessor informs the occupants the IAQ testing has been completed. At this time, the occupants may ask for the results of the assessment in their or other areas of the building. Depending on the instructions from the assessor's supervisor, the building operator or other Alberta Infrastructure Staff, the assessor may be instructed not to discuss the results with the occupants. If this is the directive, it may create uncertainty and fear in the building occupants.

Along with empathy, as discussed by Mayan (2009), personal reflection of the interviewer is important. Reflection will allow the interviewer to be honest with their own thoughts and opinions of what they are experiencing during the testing. This is done so the assessor can privately asked themselves if their own personal judgments are altering the information they are receiving. While the input from the occupants can be biased because it is their input, which reflects their own personal standards, the assessor cannot add their own standards. Reflection should occur at the time of the inspection, as well as, afterwards.

Another important factor is the assessor's level of participation in the environment. Because the philosophical basis for the inspection is Pragmatism which includes Constructivism, it is grounded in interactions and the results of these interactions. Included in these interactions are not only those taking place between the equipment and the environment, and the building occupants and the environment, but also those between the assessor and the environment. In the level of participation referred to as 'Observer as Participant' (Mayan, 2009) while the observer is there primarily to watch the situation, they will also be involved in the activity. The assessor's involvement can include their own short-term sensory input in the test locations, but not conducting the occupants' work. In those instances when the assessor does record their own sensory impressions of the built environment, this must be noted in the observation sheets as their own empirical data, and recorded as such in the IAQ Reports.

4.3. Phases of the Proposed Cross-Sectional, Convergent-Parallel, Mixed-Method Study Design

4.3.1. Determining IAQ Test Locations (Spot Tests)

A sound qualitative methodology requires a sufficient number of samples to be chosen so that saturation can occur. Mayan (2009) suggested saturation occurs when a sufficient number of samples have been determined and tested so that no new data emerges and all the leads have been followed. Ideally, there would be sufficient time for the assessor-occupant interviews to continue until the staff has adequately expressed themselves to the assessor and the optimal number of test locations has been reached. However, since the current methodology is cross-sectional, occurring over the course of one (1) day, interview time will be limited and saturation may not be possible, especially if the building is large and has many air handling units.

However, the goal of this methodology is to be sufficiently comprehensive so as to be representative of the general conditions in the building and not representative of the larger population outside of the building. Due to inherent bias and confounding factors present in setting up a mixed-method study, where the requirements of one (1) standard will affect the other, the necessary restrictions and control measures cannot be imposed to eliminate selection bias which Heckman (1979) stated can occur by using non-randomly selected samples to estimate relationships. Even if it was possible to base the sample locations solely on the building specifications, including all of the unique attributes of the air handling systems, the fact that only those areas that are, or have recently been occupied, are to be tested, will bias the results towards this population. This is especially true, if, as observed in past experience by this researcher, complaints tend to move into areas with better perceived air quality. And even if the assessor is careful in their observations, there will be a number of unique items in the environment that may confound the results without the assessor being aware of it. And without such knowledge, it is not possible to remove the possibility of a mixing of effects.

Although the results of this Indoor Air Quality methodology are inherently uncertain, measures can still be taken to reduce selection bias and confounding factors. In an attempt to balance the influence of quantitative and qualitative data, the number of non-random spot testing[5] locations chosen due to the expressed occupant IAQ concerns or complaints will be matched with an equal

[5] Spot testing is a term used for short-term IAQ testing in a test location. Spot Testing can take between 5-20 minutes per test location when Quantitative Measurements are being taken, and may take much longer for qualitative interviews.

number of randomly chosen areas that may or may not have IAQ concerns. If all of the test locations were chosen randomly, none of the occupants' IAQ concerns may be recorded, whereas, if all of the test locations were chosen non-randomly, the Final Report may give an unfair evaluation of the building's indoor air quality.

To avoid over-picking locations based on occupants' complaints/concerns in an area, the assessor should endeavour to choose qualitative responses that appear to be an average account of those areas. For example, if the assessor discovers that in one (1) area of the building ten (10) people indicate the IAQ does not meet their personal standard, the assessor will determine if all of the complaints are similar. If they are, then a fraction[6] of the total number of non-random test locations will be chosen in the area, matched by an equal number of random test locations. For completeness, in the Final Report, the assessor will clearly note the number of test locations in that one (1) area represented a larger number. The maximum number of test locations chosen for a building's IAQ Assessment should depend not only on whether the assessors believes saturation has occurred, but also if they believe they can conduct this number of tests within the one (1) day test period.

4.3.1.1. Random Spot Testing

Prior to arriving at the building, a number of test locations based on the physical parameters of the building, as well as, which areas are regularly occupied, should be chosen. The International Organization for Standardization (ISO) (2004) offered a formula (ISO 16000-1) that can be used to determine the minimal overall number of test areas:

$$N_i = 0.15 \text{ x } \sqrt{Ai} \text{ (Ni} \geq 1)$$

[6] As an initial approximation, the fraction will be set at 2O percent.

According to ISO Formula 16000-1, the minimal number of samplings point (Ni) in each zone *i* is based on the area (A_i) of the zone in m^2. This formula implies not only that there is direct relationship between square footage of a zone and the number of air samples to be taken, but also, there are no other factors that can increase or decrease the number of air samples that should be taken. However, it could be suggested there are other physical factors in the zone which can change the need to sample, factors which, as reported by Saraga et al. (2011), can add additional variances and affect the IAQ. Some of these factors include: the number of AHU supplying air to the zone; if there are areas in the zone located next to exterior windows, and does the area consist of enclosed offices and/or open spaces? In addition, does the amount of occupant activity change or stay the same in the zone? Also, areas with known containments, such as Copy and Storage Rooms, should be sampled.

If the described sections of the building are either too large or too heterogeneous, they should be further stratified into meaningful subunits based on a randomizing methodology. To subdivide the areas, a grid pattern can be placed over a copy of the building's floor plan. Each of the grid boxes, representing an average work area of 6.7 square meters - as per the GOA (2004) Ministry Accommodation Guide – is numbered. Following this, a random number generator can then choose the test locations, using N_i from the ISO 16000-1 (2004) formula as a minimal number of test locations. Ideally, prior to the assessment, the assessor will contact the building operator to ask them to indicate on the building's floor plan which areas are normally occupied and a scale so that 6.7 squared meter grids can be drawn on the plan by the assessor. This information can be sent to the assessor via email or by post. If this information is not available, then the assessor will have to acquire it on the day of the inspection and apply the aforementioned processes at that time.

4.3.1.2. Non-Random Spot Testing

Prior to the assessment, the assessor would have sent an email to the building operator or Alberta Infrastructure representative responsible for the building, describing what a BOMA IAQ Assessment entails and on what day and time it will commence. The assessor would ask if there have been any IAQ complaints and if they are aware of any of the occupants being absent due to IAQ concerns. Also, this email would recommend that the building occupants are informed of the assessment, and that anyone who has IAQ concerns should contact the operator beforehand so those areas may be selected for IAQ testing. In addition, for those occupants who would rather, they can bring up their concerns directly to the assessor when they are onsite.

During the first onsite walk-through with the building operator, the assessor would introduce themselves to the occupants and note on the building's floor plan which areas have IAQ concerns. Once the assessor has visited all occupied areas of the building, a second walk-through would commence, with them going back to selected areas with and without[7] IAQ concerns and interviewing the occupants. The selected non-random spot test locations will determine which Radom Spot Test Locations will be chosen from, based on characteristics such as being supplied by the same AHU and having a similar office configuration. The interviews will provide a forum by which the occupants may describe present and past IAQs in their area, or may inform the assessor of IAQ concerns in other areas of the building. This method is iterative, in that all information acquired is used to choose and improve the selection of the location and number of the final Spot Test Locations where the quantitative and qualitative information is measured.

[7] The areas without IAQ concerns are assumed to be in the random spot testing locations; however the occupants may inform the assessor that there are IAQ concerns.

In respect to absent-workers, an inherent concern in a cross-sectional study design, the assessor may need to interact with a number of other departments to acquire this information. Because of the Freedom of Information and Protection of Privacy (FOIP) Act (2000) does not allow outside parties, such as an assessor, to readily determine who within the building is sick, the first department the assessor should contact is the Human Resources (HR) Departments for the various government ministers within the building. The assessor or their supervisor would need to describe what type of testing would be occurring and why the information is needed. It is then up to the HR person, and the policies they are following, to make such inquiries with the occupants or their supervisors. The assessor will want to know which of these occupants possibly have IAQ related sickness and where they are located in the building.

If this information is not forth coming, then it may be possible for the assessor during their walkthroughs to note which of the work areas appear to be used, but were not occupied. From there, the assessor could ask other occupants in the area if the person at the desk is off sick. If no other information is offered, the assessor could then infer that some of the desks that had been identified as having sick workers are due IAQ-related illness. In the Final Report, the assessor will have to indicate the assumptions that have been made in choosing these locations.

4.4. Proposed Cross-Sectional, Convergent-Parallel, Mixed-Method Study Design - Results

The results or output of the BOMA IAQ Assessment would occur in keeping with the stages of a convergent, mixed-method study design, but it will not be linear. Although the study design appears sequential, it is not. Due to the process of engaging and gathering information being iterative, information from Stage Two (analyzing quantitative and qualitative measurements) can lead to further changes/measurements in Stage One (collecting quantitative and qualitative measurements) or even Stage Three (merging measurements). Nevertheless, because the primary goal of the methodology is to undertake the necessary number and type of observations/measurements to determine what the majority of the occupants' IAQ concerns are, certainty is far less important than being comprehensive. Therefore, Preliminary Results and a Final Report can still be given.

4.4.1. Preliminary Results

On the day of the inspection, during and after the assessment, onsite verbal accounts would be given to the building operator, Alberta Infrastructure Facility Manager or Operations Supervisor. As mentioned, a limited overview of the IAQ results may be given to the occupants depending on explicit instructions from the building operator or Alberta Infrastructure Staff.

4.4.2. Final Report

Within a month of the assessment, a written report would be issued to the building operator and Alberta Infrastructure Properties Staff. Others may receive the report if they have made a formal request, and have the necessary authority to make such a request. This report would include the following components: 1) quantitative and qualitative results in a table form, highlighting which results did not meet their respective standards; 2) floor plan of the location of the testing spots; 3) overview of the results including interpretation and analysis of the data in point form; followed by 4) Short and Long term recommendations for corrective actions.

For the Quantitative Results, they would be compared against Appendix 3 - Indoor Air Quality and Comfort Parameters standard defined in the Alberta Infrastructure's, Indoor Air Quality Guidelines (Government of Alberta, June 2006 (Revised June 2007)), (Appendix S). For the qualitative results, or the perceptions and observations of the occupants, this would require

Latent Content Analysis (Mayan, 2009). The first part of this process involves transcribing verbal information from the occupants. Once it is in written form, it is coded and categorized. Coding involves making the data understandable to computer software so it can be categorized based on pre-determined groupings. Prior to this, the person analyzing the data decides how similar dissimilar words are and then how to group them based on this algorithm. For example, the analyzer may determine the words 'dank' 'stuffy' and 'heavy' should be coded as meaning the same thing (low air quality). The various overlying themes are then extracted and solidified. This process will generalize, where possible, the occupant's concerns, being careful not to remove unique characteristics of individual experiences.

With this information, a number of questions can then be answered:

1. Which quantitative and qualitative data did not meet their respective standards?
2. Which quantitative and qualitative standards were breached the most and to what extent?
3. If the assessor was able to measure both quantitative and qualitative data from the same test locations, the two (2) sets of data would be compared to determine the strength of association between them. For example, there would be a high degree of association if a person said it was very hot in their area, and temperature was well above the acceptable temperature range.

Once the analysis is complete, the Final Report would then endeavour to interpret the findings. Interpretation would result in generating hypothesis for the possible causes of the IAQ concerns and developing short and long term recommendations so the IAQ parameters can meet the quantitative and qualitative standards.

4.5. Proposed Cross-Sectional, Convergent-Parallel, Mixed-Method Study Design – Assessor Self Checks for Quantitative and Qualitative Validity and Reliability

Before, during and after the Building Operator's Management Association of Canada Indoor Air Quality Assessment, the assessor and those involved in the process of testing, should conduct self-checks to ensure the methodology, as well as, their actions within the performance of the methodology are valid and reliable. As will be discussed later in this thesis, the process of verification involves ensuring academic rigour not only after the results have been acquired but during the process of acquiring them. Validity requires the involved parties to ensure what is claimed to be measured was measured. Reliability needs to be checked so that the involved parties are consistently performing their measurements in the same way. Since the entire assessment is based on the observed or empirical data, both quantitative and qualitative, this is a very important step.

4.5.1. Quantitative Self-Checks

A number of questions are proposed based on the quantitative data obtained:

1. Were the building's air handling systems and other mechanical systems related to the IAQ working within designed specifications on the day of the inspection?

2. Were the normal numbers of occupants present during the testing period? Was their level of activity normal?

3. Were the external standards used to compare the quantitative measurements against relevant and up to date?

4. Was the IAQ test equipment used to measure the standards designed to make these measurements?

5. Did the IAQ test equipment need to be calibrated and was it calibrated?

6. Were the measurements taken where the occupants are usually located during the workday and in their breathing zones?

7. Were the readings allowed to stabilize for a long enough period so that they accurately reflect the recorded environmental conditions?

8. Were there an adequate number of randomized test locations?

9. Were the physical locations of the testing areas representative of the occupied areas of the building?

10. Did the assessor accurately and precisely transcribe the equipment's readings and their own observations?

4.5.2. Qualitative Self-Checks

A number of questions are proposed based on the qualitative information obtained:

1. Did the assessor have any prior or current personal concerns or bias with the building or its operator or staff which may bias their ability to objectively conduct the assessment?

2. Were there an adequate number of non-randomized test locations chosen?

3. If possible, did the assessor attempt to determine if the occupants' perceptions of the building's IAQ was actually due to the building's IAQ and not any other stressors (possibility of confounders)?

4. If such confounder's existed, were they adequately noted in the results?

5. Were the normal numbers of occupants present during the testing period?

6. Did the assessor use open-ended questions with the occupants so that they did not lead the occupants to pre-determined conclusions the assessor was attempting to prove or disprove?

7. Did the assessor accurately and precisely transcribe the occupants' and their own observations?

The major parts of the proposed cross-sectional, convergent-parallel, mixed-method study design are summarized in Appendix Z. The methodology is divided into three (3) sections: Pre-Assessment, Assessment and Post-Assessment. The individual steps within each section are listed in chronological order. Pre-Assessment includes receiving a request for a BOMA IAQ Assessment, contacting the building operator and scheduling the assessment. Assessment includes inspecting the building's AHU(s), selecting random and non-random spot test locations, followed by taking quantitative and qualitative measurements/observations. To reduce measuring bias, the assessor should follow the specific equipment operating guidelines outlined in Appendix Z. Post-Assessment includes preliminary verbal reports and a final written report. The former will be given to the building operator on the day of the inspection, and, if permissible, a limited overview of the findings will be given to the occupants. The final written report will be issued to the building operator and Alberta Infrastructure Staff.

5.0. Discussion and Recommendations

5.1. Discussion

The proposed cross-sectional, convergent-parallel, mixed-method study design for conducting BOMA IAQ Assessments in GOA owned and leased buildings, simultaneously measures data from both the built environment and its associated system (quantity) and from the occupants (quality). By obtaining data from both sources in parallel, and comparing them against each other, this allows the researcher to not only assess if the individual standards have been met, but also the level of association between quantitative and qualitative data.

Even if one of these data streams is qualitative, and inherently biased, Verification is a necessary step in ensuring the methodology and any of its conclusions are not fiction. Morse et al. (2002) defined Verification as a process of ensuring the data was obtained and interpreted within the limitations of the study design. If findings of the research are reliable and valid, then the rigor of the study increases. The present thesis adopts the view both quantitative and qualitative data have to be valid and reliable, and Verification Strategies are not only to be applied once the data had been obtained, it also has to occur while the data is being obtained.

For the proposed cross-sectional, convergent-parallel, mixed-method study design, Verification of the quantitative parameters requires the appropriate and relevant externally measurable IAQ parameters to be chosen and measured. As outlined previously, the list of Indoor Air Quality quantitative parameters that are to be used in the proposed methodology are from professional organizations with recognized and relevant expertise, including ANSI/ASHRAE (Standard 55 (2013b), Standard 62.1 (2013a), Best Practices for Design (2009)), Alberta Infrastructure (Indoor air Quality: Mould Indoor Environments Risk Assessment and Management Program Handbook

(2006)) and Alberta Health Services (Environmental Public Health Indoor Air Quality Manual (2012)). The American Society of Heating, Refrigerating and Air-Conditioning has recognized expertise in the design and functioning of the air handling and related systems of the ventilation and thermal controls of the building, while Alberta Infrastructure and Alberta Health Services are experts as to which physical, chemical and biological agents may be present in the built environment, and what levels of these agents should be present in an healthy and comfortable environment. Furthermore, Alberta Infrastructure and those private and public parties they interact with, have the necessary quantitative expertise to purchase and use the equipment necessary to make the cited IAQ measurements.

Although there is at present no recognized qualitative standard or methodology to conduct proactive Indoor Air Quality inspection, the present methodology is based both on field experiences of the Building Environment Unit, as well as, from the previously cited articles. Furthermore, the IAQ Assessor is to self-check for validity and reliability throughout the methodology to ensure the necessary conditions exist, so that the defined measurements are correctly measured. If, as required, the assessor has expertise in both quantitative and qualitative research as it applies to testing in built environments, they will be aware of the need for continual validation and consistency. In addition, even though the testing is cross-sectional, and occurring on only one day, implying the quantitative results may be biased to the Indoor Air Quality on that day, the qualitative input acts as a form of 'data mining' providing a means to 'look into the IAQ history of the building.' As such, since most of the information from the occupants will be from their long-term exposure to conditions within the building, this methodology helps the assessor to optimize their historical understanding of the building's IAQ, and therefore, increases the validity of the method.

Generalizability is also another aspect of academic rigour, and one often overlooked by qualitative researchers. Because the present methodology collects data from individuals, it appears difficult to argue the information gained can be generalized to other people with their own unique standards. Morse (1999) however did not view inherent variability as a liability. Instead, diversity is desired; samples in relatively small samples sizes should be selected purposefully so they can contribute toward the emerging theory. Ideally, each sample should be a composite of the many other characteristics within the population. In other words, the researcher is supposed to challenge previous theories with new samples to see if they fit, or if the theory needs to be adjusted. As such, the paradigm is shifted from proving the theory is correct, to testing if it is incorrect. It is the specific selection of these samples that ensures the theory is comprehensive, complete, saturated, and accounts for negative cases. If carefully selected, knowledge gained from these samples should be valid for all likely scenarios that may be identified in the larger population.

To examine this closer, a hypothetical example is considered. In a particular building there is a strong association between occupants complaining of dryness (i.e. low relative humidity) (quantitative) and the occupants' perception of experiencing sore throats (qualitative). This information and not the fact certain individuals had the perceptions is what is relevant. As such, it is not the individual, but the aggregated experiences that are generalizable. Once this information is put into the report, it will be recommended the relative humidity throughout the building be increased to an acceptable range, with the expectation that such an adjustment would have a positive effect not only for those who voiced these concerns, but for others within the building who were not interviewed but may also had similar symptoms.

For the proposed methodology, the primary strength and weakness is the ability of the assessor to fulfil their assigned tasks. Even if the data that is chosen to be collected and the standards by which they are compared against, are a valid reflection of the building's Indoor Air Quality, and the method is, in theory, reliable (consistent), so much of the success of the assessment lies squarely on the assessor. The assessor is asked to have both quantitative skills: observant, factual and precise; as well as, qualitative skills: creativity, sensitivity, flexibility and adaptability. Such divergent skills sets may be very difficult to find in a single assessor. If this is not possible, or even likely, it reduces the probability that Verification will occur.

To improve validity and reliability of the assessor, and thereby improve the overall assessment of the indoor air quality, it could be suggested more than one (1) person should perform the testing. Given the experience of the Building Environment Unit with employing only one (1) person to conduct the BOMA IAQ Assessment, the aforementioned methodology is a very long and exacting process. It involves and requires the assessor to often conduct the assessment for more than eight (8) hours in a row (approximately from 8:00 am to 4:30 pm). As such, it appears that having two (2) or even three (3) assessors present at the same time will greatly reduce the time and efforts of the individual assessor.

If there is only one (1) assessor, they are being tasked to not only take quantitative measurements, but to also to interview the occupants and look for aspects of the environment that may be related to the findings. If, on the other hand, one person took the physical measurements (quantitative) and another interviewed the occupants (qualitative), it is possible, and as long as each assessor does not cross over into the other's scope of duty, this would increase the consistency of each type of testing. The choice of the testing spots would then fall upon the person who is assigned to interview the occupants to decide the location and number of non-random test locations, and then, either with the second assessor, or by themselves, to follow the random spot testing protocols to choice the other locations. Although two (2) assessors could improve the assessment's validity and reliability, and some organizations may be able to provide an extra person, at present, it is unknown if the Built Environmental Unit of Alberta Infrastructure can provide the additional assessors.

Even if the optimal level of assessors may not be available to maximize the performance of the assessments, the process of engaging the occupants has a number of positive attributes. Based on the researcher's experience in Building Environment Unit during initial BOMA IAQ Assessments, it became evident that by involving the occupants in the testing, not only made the assessment more comprehensive, the occupants' involvement seemed to improve their understanding/appreciation of the building's capacity to meet their expectations. For example, if the occupants wanted it hotter, but the temperature in their area was within the acceptable temperature range of 20 – 24 degrees C, many occupants seemed to accept the heating system could only provide temperatures within this range.

Furthermore, by directly interacting with occupants, one could better understand the framework of their concerns and expectations. Often, when occupants were forthcoming about their perception of unacceptable Indoor Air Quality, they readily displayed behaviours which implied they were either experiencing discomfort or anxiety. Such anxiety was often compounded because it appeared the occupants did not know how to report the information. This observation is particularly helpful for the purposes of the assessment because it speaks directly to whether the building operator has a means of being aware of and then addressing the occupant's IAQ complaints, a question that was stated in the Building Owners and Managers Association of Canada (BOMA), June 2009 document.

Furthermore, as it was experienced by this researcher, that even if there were IAQ parameter(s) that did not meet a standard, careful disclosure of information to the occupant by stating the information in its proper context, drew minimal occupant overreactions. If an overreaction occurred, the BEU Researcher gave further explanation. Any unresolved overreactions the BEU were aware of were reported to the Alberta Infrastructure Properties Division contact. When there was an apparent deficiency in the IAQ and if the BEU Researcher/Assessor was given the authority to discuss the information with the occupants, the researcher would say to the occupants the measurements would be noted in the report and corrective actions would be recommended to the building operator. To many of the building occupants this response appeared to be sufficient. In addition, and to build trust, the BEU Researchers would also mention to the occupants that if any of the IAQ test equipment readings indicated there were dangerous levels of contaminants in the building, they would immediately inform them and contact the building operator. Either way, by engaging the occupants and showing them genuine concern and respect, the occupants often felt heard and understood which appeared to reduce their anxiety.

By talking to occupants about their IAQ concerns in an open, non-judgmental fashion, this methodology allowed the BEU Researcher/Assessor to show empathy. This allowed the occupants not only to be honest about their perceptions, but also more accepting of the information they were given. By providing a process to validate that they had these perceptions, it began to reduce their anxiety. The message the BEU Researcher/Assessor attempted to give to the occupants was: ‘We hear you have this perception, and to you it is correct. We will not judge it. We will write it down and then we will perform the necessary IAQ measurements so we may better understand your perceptions and try to confirm the correlation.’

The BEU Researchers also believed the methodology helped the occupants feel empowered in respect to their Indoor Air Quality concerns. Instead of endorsing the mindset that the quality of the indoor air was too difficult for the occupants to understand or unrelated to their health and comfort, the viewpoint of the methodology is inclusive, and not condescending or authoritarian. The Constructivist-Pragmatic Philosophy requires open, respectful exchanges of information and in the formation of what is acceptable. And by directly involving the occupants in the discussion of what may be the cause(s) of the IAQ perception, not only could the occupants begin to see they had an important role in its monitoring, but as valued members of the discussion, be objectively informed that Alberta Infrastructure had limited resources to operate and manage GOA Buildings. From there, occupants could begin to relate or at least understand the difficulties the building management had in maintaining the building, and perhaps appreciate that it was necessary to work with the operators to resolve the concerns. The BEU always had in mind the idea of trying to move both the operator and the occupants away from the 'us' and 'them' mindset that can often complicate communications.

In light of this information and arguments formed upon it, it is now possible to re-visit American Standard of Heating Refrigeration and Air Conditioning Engineers definition of acceptable Indoor Air Quality. As stated within the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 55 (2013b) and Standard 62.1 (2013a), the purpose/scope of these documents is to specify the ventilation or heating systems parameters of a building so both the 'thermal comfort' or the level of 'contaminants' will be suitable for 80% of the occupants. At the time this information was previously given, it was asked what is to be done about the other 20% of the people who are not satisfied. Two (2) possible responses are offered to this question: (1) as outlined in the previous paragraph involves engaging the occupants, taking the necessary measurements to quantify the concern, followed by discussing the results with the building operator and the occupants. Then, within the limitations of the building's mechanical systems to achieve favourable conditions, recommend possible ways to amend the environmental conditions. (2) Or, as given by the second option, ignore such concerns.

The question then becomes what could happen if the Indoor Air Quality concerns of the occupants are ignored, or turned into a 'problem' of those who expressed them? While some occupants may accept the building operator's willingness to take no further action, or perhaps understand the implication posed by most environmental conditions (excluding high level of carbon monoxide) is actually not 'scientifically' significant, there will be occupants who may feel very concerned IAQ issues are not being addressed by the building operator. Boxer's (1990) work appears to describe what may happen as a consequence of not adequately respecting and engaging the occupants. Boxer (1990) discusses a phenomenon referred to as Mass Psychogenic Illness (MPI), in which there is the rapid spread of symptoms whose basis lies in psychological factors. The 'outbreak' begins with one (1) or several workers becoming ill, most of which attribute their symptoms to a physical cause in the work environment. As the word of the occurrence spreads throughout the building, so does the anxiety build up, resulting in other workers becoming ill with numerous symptoms and complaints.

The reason this may be pertinent to IAQ is, as Boxer (1990) suggested, there is a strong link between MPI and those symptoms reported by occupants during a Sick Building Syndrome investigation. Although the proposed cross-sectional, convergent-parallel, mixed-method study design is proactive, and would not be used in response in a facility with complaint-driven, Sick Build Syndrome, such a situation may have arisen because of the building operator or associated staff not initially engaging the occupants. For example, even if the occupants may not openly disagree with operator’s inability to engage them in some way, to at least discuss why their perceived Indoor Air Quality concerns may or may not be a health issue, it is possible for the occupants’ internal anxiety to cause a small issue that could be rationally approached, to one requiring more resources to rectify, and possibly leading to future tension between the occupants and building operator.

Furthermore, as observed by this researcher, some of the stakeholders expressed concerns during the initial phases of BOMA IAQ Assessments, including the building operator and Alberta Infrastructure Staff, either directly or indirectly, about involving the building occupants in the assessments. To them, occupant’s input was irrelevant, and including it or asking for it or responding to it, would cause problems. Some building operators indicated to BEU Researchers that by discussing IAQ results with the occupants or even having the occupants present during testing was provocative and would unnecessarily alarm the occupants. For the latter concern, this implied the assessor would give information to the occupants about conditions of the building that was incorrect. However, since the information the assessor would have would be from either the instruments, which are assumed to be calibrated and correct, or from specific occupants being interviewed, which they already know, it could be inferred the operator is actually saying something else. It could be hypothesized that perhaps the operator is implying that they should decide if and when the occupants have this information and in what form. Regardless of whether the operator’s request goes against the Government of Alberta mandates, or OHS practices, by not treating the occupants with respect and responding to the occupant’s direct requests for information at the time of the inspection, can quickly disengage the building’s occupants.

Or, it is hypothesized that perhaps the building operators or equivalent managers were of the opinion the standard of the assessment was only quantitative; and did not include qualitative data. By taking the former view, the occupant's perceptions/standards are not considered to be relevant. This last comment allows the researcher to offer another example of dissimilar objectives creating divergent expectations, one that is fundamental to the Building Operator's Managers Association BESt certification process. At present, there are four (4) levels of BOMA BESt Certification (2014), and depending on how many points a building earns in the various categories, the higher the level it will achieve. The highest level, Certification Level Four requires an overall building score of 90% or more. With the score being an overall average, it means that even if the building fails in one of the smaller areas, of which IAQ falls within, the building may still achieve a high overall score. And even more potentially adverse, is the reliance of the BOMA system for the operators to manage themselves, undermining the ability of an auditing system to have any form of meaningful objectivity. From this, it is clear that there are two (2) different and potentially conflicting expectations of the BOMA IAQ Assessment; the first is for optimizing the 'health' and 'comfort' of the occupants, while the other is for obtaining the highest BOMA Certification Standard.

5.1.1. Overview of the Strengths of the Methodology

This list of strengths is offered with the proviso that the necessary resources, including personnel and equipment are available to fully implement the methodology:

1. Valid – The methodology produces a more comprehensive picture of the IAQ in the building, not only on the day of the testing, but throughout the year.

2. Reliable – The methodology is designed to provide a method to consistently monitor/observe quantitative and qualitative data in GOA buildings it is applied to.
3. Generalizability - The measurements and the subsequent associations arrived at from conducting the IAQ Assessment at one (1) particular GOA buildings can be applied to other GOA buildings.
4. Efficient – Cross-sectional, mixed-method study design allows for testing to be completed in one (1) day.
5. By including input from the occupants, which may include their present and past experiences, there is less variance in the results, in comparison to quantitative data that is only acquired on the day of the assessment.
6. The assessment may include information from Absent Workers, whose absenteeism could be IAQ related.
7. Increased engagement/communication with occupants.
8. Empower the occupants to better understand what may or may not be the cause of their perceptions, and their responsibilities in reporting their concerns.
9. Decrease the occupants' IAQ anxiety by discussing IAQ conditions in their area in a rational, empathic and professional manner.
10. Less 'interpretative noise' than other qualitative methods.

5.1.2. Overview of the Weaknesses of the Methodology

This list of weaknesses is offered with the proviso that the necessary resources, including personnel and equipment are available, but are operating under duress or suboptimal conditions:

1. Reliance on Expertise - Assessment Staff requires expertise in quantitative and qualitative research. If the assessment is performed by only one (1) assessor, the necessary level of individual expertise increases.
2. Physically and psychologically intensive.
3. Assessor's viewpoint may be deductive and not inductive. This occurs if the assessor does not listen or appreciate the individual occupants' unique perceptions.
4. Selection/Interview Bias:
   i. Healthy Worker – If information concerning absent workers is not collected, then only healthy workers could be present at the time of the inspection. Those occupants with long-term IAQ issues may be home on the day of the inspection, thereby affecting the results.
   ii. Seasonal: Testing during a certain time of year may cause the building to exhibit some issues, but not others. For example, a weak heating system would not be evident in the summer.
   iii. Testing Locations: Difficult to mix the opposing needs of quantitative (all locations have an equal chance of being picked) with qualitative (locations chosen where occupants have IAQ concerns) Data.
   iv. Assessor may allow one (1) standard to produce a preformed opinion and bias their ability to measure the other group of measurements.
5. Confounding Factors:
   i. Occupant Stress: Occupant workload or other life factors could increase their tendency for them to be sensitive to the IAQ of a building. Although the assessor is not an authority in what may or may not cause an occupant stress,

the assessor should note this information, where it is apparent to them, if they believe the occupants may be affected by such a factor, which could alter the occupants' perception of how the IAQ is affecting them.

ii. Occupant Health Issues: Occupants' general health (i.e. flu season) could be the reason for IAQ complaint and not the building's IAQ.

iii. Assessor Stress: Assessor's workload or other life factors could increase their tendency to perceive a building as being the cause of IAQ concerns voiced by the occupants. Although the assessor may not be able to control these emotions and/or thoughts, they need to be aware of them, and note them in the final report.

iv. Other elements in the internal or external environment which may be affecting the occupant's perception of a building's Indoor Air Quality and not observed and noted in the report.

6. Indoor Air Quality Testing Equipment

   i. Not calibrated.

   ii. Inadequate to take the required measurements. The ambient levels of the parameters are below the detection limit of the equipment.

   iii. The equipment is faulty, may produce false-positive or false-negative readings.

7. Occupants may not communicate their IAQ concerns to the assessor:

   i. Too busy.

   ii. Environmental conditions.

   iii. Language barriers.

   iv. Intimidated by other occupants or the building operator.

v. Apathy of occupants or building operator.

vi. Short-term illness.

8. External Interference – Since the Building Environment Unit is not independent of other parts of the government, other stakeholders with more influence over the process can subvert the methodology:

   i. Building Operator/Alberta Infrastructure Staff may manipulate the process. They can ask the assessor not to discuss the findings with the occupants.

   ii. Building Operator may not consider or undertake any of the recommendations.

9. Upset/ Alarm Occupants

   i. At the time of the assessment, the quantitative readings may upset the occupants.

   ii. If, after the testing the occupants ask for the results and are informed by the assessor that the information cannot be immediately shared with them, this may cause the occupants to become anxious due to either believing the results are being withheld because they are 'bad' or the assessor has other reasons for not sharing them.

5. Lack of follow-up of findings and recommendations.

6. Findings may upset Building Operator: Data either from occupants or from measuring the building and its systems may imply that the building operator is not performing their work correctly which may cause conflict with the occupants of the building or the operator's supervisors.

7. Mechanical system failures on the day of the assessment, not representative of the normal functioning.

5.2. Recommendations

Based on this researcher's experiences, there were three (3) distinct phases the Building Environment Unit of Alberta Infrastructure experienced while formulating a proactive method for assessing Indoor Air Quality in Government of Alberta Buildings for BOMA. In Phase I, when the BEU first began to conduct inspections proactively, a number of quantitative parameters were defined and used to measure the IAQ (Appendix A) during either the morning or afternoon. The occupants were seldom asked about their perceptions of the building's Indoor Air Quality.

With time and upon considering the misunderstandings of the initial assumptions[8], the BEU shifted into Phase II. In Phase II, it was understood by the majority of the BEU members that since the initial assessments did not associate specific areas of the building with specific occupants' symptoms that may be related to IAQ, and may affect the occupants' perception of the building's indoor air quality, the BEU began to engage the occupants with more open-ended questions. The assessments also began to measure more quantitative variables, including pressurization between areas (Appendix C and D). Assessing also occurred throughout the workday because the BEU came to realize IAQ testing in the morning and afternoon was a better means of measuring how a building's mechanical systems adapted to changes in external (weather) and internal (number of occupants, changes in activities) conditions.

Phase III involves the present methodology proposed by this researcher, and how best to progress with lessons learned during the testing period. It should be noted that while most of what is described in this thesis has taken place during PHASE II, some of it has not. One of the

[8] As discussed in Section 1.2.1, Background

key aspects not performed during PHASE II was ensuring that the number random and non-random spot testing locations were equal. As indicated in the methodology proposed here, during the walk-through, the test locations are to be chosen based on a number of random and non-random parameters, including the occupants' IAQ concerns.

The primary recommendation of this thesis is to field test the effectiveness of the proposed cross-sectional, convergent-parallel, mixed-method study design for the Assessment of Indoor Air Quality (IAQ) in Alberta Government Buildings. This should be done to compare the current Occupant-Centred Methodology with the more Building-Centred design previously employed by the BEU at the beginning of the initial field work during PHASE I. This would be done primarily to determine how well each method is able to detect variables not meeting the quantitative standards, as well as, measure the occupant's perception of the how well each IAQ Assessment Methodology is able to represent their own IAQ concerns. Furthermore, the two (2) methodologies can be compared in how well they are able to help the assessor become aware of their own bias and other confounding factors which may affect the results. And lastly, the two (2) methodologies can be compared in terms of validity, reliability, and generalizability.

Another recommendation, perhaps undertaken if the previous results have sufficient academic rigor, is to consider the possibly of having this methodology performed by an independent third party. One of the initial arguments given by the BEU for supporting this thesis and the associated research was to produce a standard format for performing BOMA IAQ Assessments, a format that could not only be used by the Building Environment Unit of Alberta Infrastructure, but also as a set of instructions for the private sector. Since the Building Environment Unit has a limited number of staff, if the private sector was able to perform this labour intensive work, it would free members of the Building Environment Unit Staff to conduct other important work.

In addition, through carrying out this type of work, and understanding the importance of engaging the building occupants, it may be possible for private sector companies to change their own perspective on how to conduct IAQ Inspections/Investigations, either reactive or proactive. It is the experience of this researcher that a number of companies rely too heavily on limited quantitative data to arrive at their conclusions.

For each specific building assessed either by the Government of Alberta Staff or by the private sector, the outcome of such research could be used to construct qualitative theories for Government of Alberta Buildings in general. Although the information for each site is inherently unique and cannot be generalized to all government buildings the possibility exists that the overall lessons and general concerns discovered can be applied to other buildings in similar areas or with similar purposes. By employing the features inherent in Grounded Theory to construct theory based on the analysis of accrued data from multiple buildings tested during PHASE III BOMA IAQ Assessments, it may be possible to list which quantitative and qualitative measures and/or descriptors have the strongest associations with each other; which quantitative measures most readily do not meet the external (objective) standards; and which quantitative measures are most readily associated with the perception (internal standard) of unacceptable IAQ.

The strongest recommendation of this researcher is for everybody involved in BOMA IAQ Assessments to have similar expectations of the process. As discussed within the literature review (field experience), some occupants informed the BEU Research Group that they believed the building operator may request a BOMA IAQ Assessment with the intent of not following the recommendations. Although it is not possible, nor appropriate to speculate on the motivations of a building operator, Siegrist and Cvetkovich (2000) discovered people without the necessary experience or technical knowledge to assess complex hazards, often base their perception of how hazardous an item is on how much they trust those who manage such items. Therefore, if a number of building's occupants do not trust the building operator based on previous experiences, and are also aware the building operator is not required to consider or follow the recommendations of the BOMA IAQ Assessment, this may lead the occupants to speculate that the IAQ is poorer than it actually is and increase the level of anxiety in these occupants.

If this is the case and the BEU does not currently have any means to ensure all building operators adhere to the same standard, perhaps it could be recommended that different types of BOMA IAQ Assessments should be performed based on the explicit directions of those who request the assessments. It could be suggested that when the Building Environment Unit is contacted in the future by a building operator or Alberta Infrastructure Staff to conduct a BOMA IAQ Assessment, the person requesting the assessment clearly states in writing what type of assessment they wish to have performed. Therefore, whether the client requests a 'building' or 'occupant-centered' IAQ Assessment, the intended standard by which the empirical data is judged against would be clearly identified in the Final Report.

Such clarification of the type of assessment required could possibly improve the efficiency of BOMA IAQ Assessments. By the requester clarifying up front what type of assessment they require, it would allow the Building Environment Unit and other third party consultants to better allocate their resources. Conducting an occupant-centered assessment in GOA buildings where the requester only wanted a building-centered assessment is inefficient. And in situations where a building-centered assessment is being conducted, such clarification may also result in the occupants of the building asking the requester why a less comprehensive BOMA Indoor Air Quality Assessment was being conducted in their building.

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Appendices

Appendix A:

Government of Alberta, Spring 2011, Alberta Infrastructure, Initial BOMA IAQ Assessment Guide

BOMA IAQ testing:

We inspect and test 10 – 20 occupied areas only in a building for:

- **Temperature**, **relative humidity**, **carbon dioxide** and **carbon monoxide**, ensuring all floors and air systems are tested.
- **Ambient dust** at the same locations.
- Total volatile organic compounds (**TVOC's**) only where odours are noticed.
- **Formaldehyde** only where odours are noticed.
- Lighting levels at the same 10 to 20 locations.
- Supply and return airflow at the same 10 to 20 locations.

LEED IAQ testing:

We inspect and test 10 - 20 occupied areas in a building for:

- **Temperature**, **relative humidity**, **carbon dioxide** and **carbon monoxide**, ensuring all floors and air systems are tested.
- **Ambient dust** at the same locations.
- Check same locations for any **water damage or mould**.
- Inspect same locations for **visible dust**.

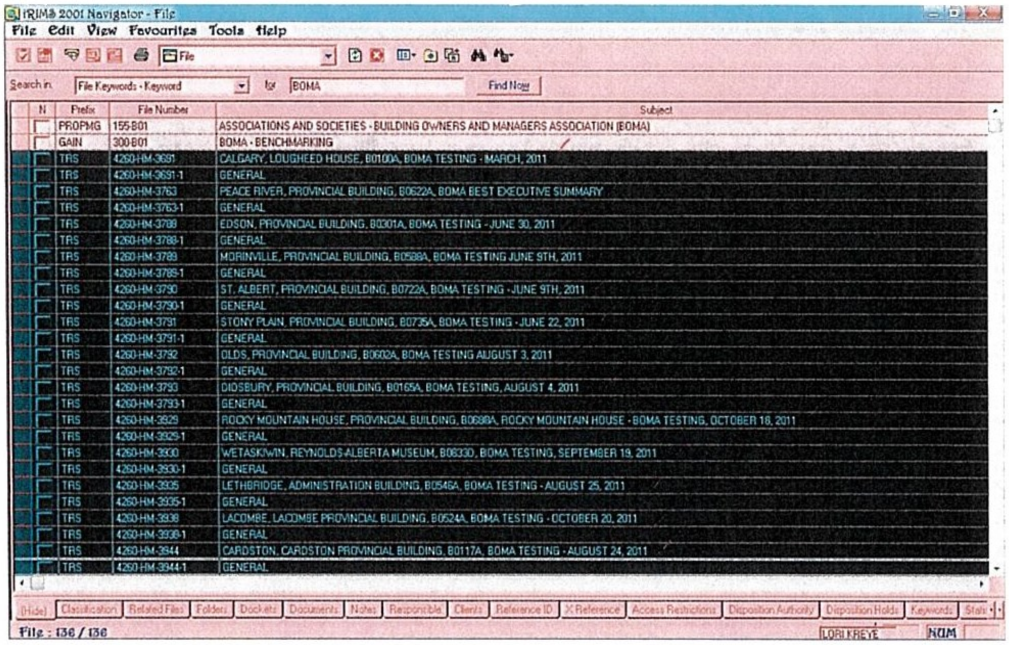
We would test 10 – 20 unoccupied areas for:

- **All of the above plus**,
- Total volatile organic compounds (**TVOC's**)
- **Formaldehyde**

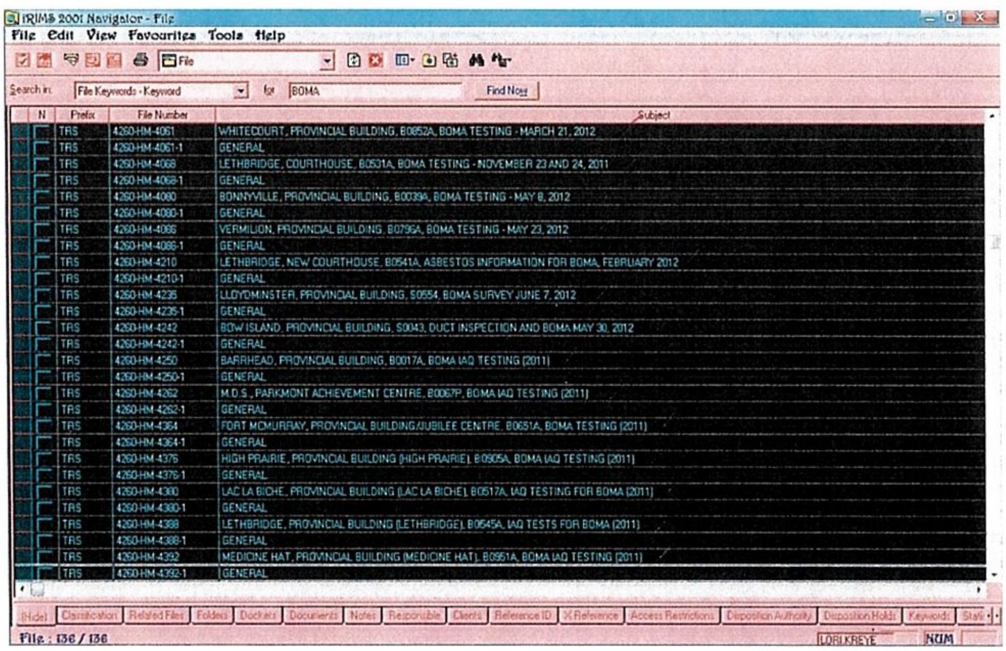
(We do not test occupied areas for total volatile organic compounds (TVOC's) or formaldehyde, because sometimes people's clothing can affect readings).

Appendix B:

Government of Alberta, 2014, Records' Listing of 2011 – 2014 BOMA IAQ Assessments



Prefix	File Number	Subject
PROPMG	155-B01	ASSOCIATIONS AND SOCIETIES - BUILDING OWNERS AND MANAGERS ASSOCIATION (BOMA)
GAIN	300-B01	BOMA - BENCHMARKING
TRS	4260-HM-3691	CALGARY, LOUGHEED HOUSE, B0100A, BOMA TESTING - MARCH, 2011
TRS	4260-HM-3691-1	GENERAL
TRS	4260-HM-3763	PEACE RIVER, PROVINCIAL BUILDING, B0622A, BOMA BEST EXECUTIVE SUMMARY
TRS	4260-HM-3763-1	GENERAL
TRS	4260-HM-3788	EDSON, PROVINCIAL BUILDING, B0301A, BOMA TESTING - JUNE 30, 2011
TRS	4260-HM-3788-1	GENERAL
TRS	4260-HM-3789	MORINVILLE, PROVINCIAL BUILDING, B0588A, BOMA TESTING JUNE 9TH, 2011
TRS	4260-HM-3789-1	GENERAL
TRS	4260-HM-3790	ST. ALBERT, PROVINCIAL BUILDING, B0722A, BOMA TESTING - JUNE 9TH, 2011
TRS	4260-HM-3790-1	GENERAL
TRS	4260-HM-3791	STONY PLAIN, PROVINCIAL BUILDING, B0735A, BOMA TESTING - JUNE 22, 2011
TRS	4260-HM-3791-1	GENERAL
TRS	4260-HM-3792	OLDS, PROVINCIAL BUILDING, B0602A, BOMA TESTING AUGUST 3, 2011
TRS	4260-HM-3792-1	GENERAL
TRS	4260-HM-3793	DIDSBURY, PROVINCIAL BUILDING, B0165A, BOMA TESTING, AUGUST 4, 2011
TRS	4260-HM-3793-1	GENERAL
TRS	4260-HM-3929	ROCKY MOUNTAIN HOUSE, PROVINCIAL BUILDING, B0688A, ROCKY MOUNTAIN HOUSE - BOMA TESTING, OCTOBER 18, 2011
TRS	4260-HM-3929-1	GENERAL
TRS	4260-HM-3930	WETASKIWIN, REYNOLDS-ALBERTA MUSEUM, B0633D, BOMA TESTING, SEPTEMBER 19, 2011
TRS	4260-HM-3930-1	GENERAL
TRS	4260-HM-3935	LETHBRIDGE, ADMINISTRATION BUILDING, B0546A, BOMA TESTING - AUGUST 25, 2011
TRS	4260-HM-3935-1	GENERAL
TRS	4260-HM-3938	LACOMBE, LACOMBE PROVINCIAL BUILDING, B0524A, BOMA TESTING - OCTOBER 20, 2011
TRS	4260-HM-3938-1	GENERAL
TRS	4260-HM-3944	CARDSTON, CARDSTON PROVINCIAL BUILDING, B0117A, BOMA TESTING - AUGUST 24, 2011
TRS	4260-HM-3944-1	GENERAL



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TRS	4260-HM-4061	WHITECOURT, PROVINCIAL BUILDING, B0852A, BOMA TESTING - MARCH 21, 2012
TRS	4260-HM-4061-1	GENERAL
TRS	4260-HM-4068	LETHBRIDGE, COURTHOUSE, B0531A, BOMA TESTING - NOVEMBER 23 AND 24, 2011
TRS	4260-HM-4068-1	GENERAL
TRS	4260-HM-4080	BONNYVILLE, PROVINCIAL BUILDING, B0039A, BOMA TESTING - MAY 8, 2012
TRS	4260-HM-4080-1	GENERAL
TRS	4260-HM-4086	VERMILION, PROVINCIAL BUILDING, B0796A, BOMA TESTING - MAY 23, 2012
TRS	4260-HM-4086-1	GENERAL
TRS	4260-HM-4210	LETHBRIDGE, NEW COURTHOUSE, B0541A, ASBESTOS INFORMATION FOR BOMA, FEBRUARY 2012
TRS	4260-HM-4210-1	GENERAL
TRS	4260-HM-4236	LLOYDMINSTER, PROVINCIAL BUILDING, S0554, BOMA SURVEY JUNE 7, 2012
TRS	4260-HM-4236-1	GENERAL
TRS	4260-HM-4242	BOW ISLAND, PROVINCIAL BUILDING, S0043, DUCT INSPECTION AND BOMA MAY 30, 2012
TRS	4260-HM-4242-1	GENERAL
TRS	4260-HM-4250	BARRHEAD, PROVINCIAL BUILDING, B0017A, BOMA IAQ TESTING (2011)
TRS	4260-HM-4250-1	GENERAL
TRS	4260-HM-4262	M.D.S., PARKMONT ACHIEVEMENT CENTRE, B0067P, BOMA IAQ TESTING (2011)
TRS	4260-HM-4262-1	GENERAL
TRS	4260-HM-4364	FORT MCMURRAY, PROVINCIAL BUILDING/JUBILEE CENTRE, B0651A, BOMA TESTING (2011)
TRS	4260-HM-4364-1	GENERAL
TRS	4260-HM-4376	HIGH PRAIRIE, PROVINCIAL BUILDING (HIGH PRAIRIE), B0905A, BOMA IAQ TESTING (2011)
TRS	4260-HM-4376-1	GENERAL
TRS	4260-HM-4380	LAC LA BICHE, PROVINCIAL BUILDING (LAC LA BICHE), B0517A, IAQ TESTING FOR BOMA (2011)
TRS	4260-HM-4380-1	GENERAL
TRS	4260-HM-4388	LETHBRIDGE, PROVINCIAL BUILDING (LETHBRIDGE), B0545A, IAQ TESTS FOR BOMA (2011)
TRS	4260-HM-4388-1	GENERAL
TRS	4260-HM-4392	MEDICINE HAT, PROVINCIAL BUILDING (MEDICINE HAT), B0951A, BOMA IAQ TESTING (2011)
TRS	4260-HM-4392-1	GENERAL

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	GAIN	300-B01	BOMA - BENCHMARKING
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	TRS	4260-HM-3793-1	GENERAL
	TRS	4260-HM-3929	ROCKY MOUNTAIN HOUSE, PROVINCIAL BUILDING, B0680A, ROCKY MOUNTAIN HOUSE - BOMA TESTING, OCTOBER 18, 2011
	TRS	4260-HM-3929-1	GENERAL
	TRS	4260-HM-3930	WETASKIWIN, REYNOLDS-ALBERTA MUSEUM, B0833D, BOMA TESTING, SEPTEMBER 19, 2011
	TRS	4260-HM-3930-1	GENERAL
	TRS	4260-HM-3935	LETHBRIDGE, ADMINISTRATION BUILDING, B0546A, BOMA TESTING - AUGUST 25, 2011
	TRS	4260-HM-3935-1	GENERAL
	TRS	4260-HM-3938	LACOMBE, LACOMBE PROVINCIAL BUILDING, B0524A, BOMA TESTING - OCTOBER 20, 2011
	TRS	4260-HM-3938-1	GENERAL
	TRS	4260-HM-3944	CARDSTON, CARDSTON PROVINCIAL BUILDING, B0117A, BOMA TESTING - AUGUST 24, 2011
	TRS	4260-HM-3944-1	GENERAL

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	TRS	4260-HM-4061-1	GENERAL
	TRS	4260-HM-4068	LETHBRIDGE, COURTHOUSE, B0531A, BOMA TESTING - NOVEMBER 23 AND 24, 2011
	TRS	4260-HM-4068-1	GENERAL
	TRS	4260-HM-4080	BONNYVILLE, PROVINCIAL BUILDING, B0039A, BOMA TESTING - MAY 6, 2012
	TRS	4260-HM-4080-1	GENERAL
	TRS	4260-HM-4086	VERMILION, PROVINCIAL BUILDING, B0796A, BOMA TESTING - MAY 23, 2012
	TRS	4260-HM-4086-1	GENERAL
	TRS	4260-HM-4210	LETHBRIDGE, NEW COURTHOUSE, B0541A, ASBESTOS INFORMATION FOR BOMA, FEBRUARY 2012
	TRS	4260-HM-4210-1	GENERAL
	TRS	4260-HM-4235	LLOYDMINSTER, PROVINCIAL BUILDING, S0654, BOMA SURVEY JUNE 7, 2012
	TRS	4260-HM-4235-1	GENERAL
	TRS	4260-HM-4242	BOW ISLAND, PROVINCIAL BUILDING, S0043, DUCT INSPECTION AND BOMA MAY 30, 2012
	TRS	4260-HM-4242-1	GENERAL
	TRS	4260-HM-4250	BARRHEAD, PROVINCIAL BUILDING, B0017A, BOMA IAQ TESTING (2011)
	TRS	4260-HM-4250-1	GENERAL
	TRS	4260-HM-4262	M.D.S., PARKMONT ACHIEVEMENT CENTRE, B0067P, BOMA IAQ TESTING (2011)
	TRS	4260-HM-4262-1	GENERAL
	TRS	4260-HM-4364	FORT MCMURRAY, PROVINCIAL BUILDING/JUBILEE CENTRE, B0651A, BOMA TESTING (2011)
	TRS	4260-HM-4364-1	GENERAL
	TRS	4260-HM-4376	HIGH PRAIRIE, PROVINCIAL BUILDING (HIGH PRAIRIE), B0905A, BOMA IAQ TESTING (2011)
	TRS	4260-HM-4376-1	GENERAL
	TRS	4260-HM-4380	LAC LA BICHE, PROVINCIAL BUILDING (LAC LA BICHE), B0517A, IAQ TESTING FOR BOMA (2011)
	TRS	4260-HM-4380-1	GENERAL
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	TRS	4260-HM-4388-1	GENERAL
	TRS	4260-HM-4392	MEDICINE HAT, PROVINCIAL BUILDING (MEDICINE HAT), B0961A, BOMA IAQ TESTING (2011)
	TRS	4260-HM-4392-1	GENERAL

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Appendix C:

Government of Alberta, February 2 2012, Alberta Infrastructure, Revised BOMA IAQ Assessment Guide

BOMA IAQ testing (revised as of February 2, 2012):
(*new test)
We inspect and test 10 – 30 occupied areas in a 1 to 4 storey building (depending on size), or 4 – 6 occupied areas per floor in a highrise building (greater than 4 floors) for:

- **Temperature**, **relative humidity**, **carbon dioxide** and **carbon monoxide**, ensuring all floors and air systems are tested.
- **Ambient dust** at the same locations.
- **Total volatile organic compounds** (**TVOC's**) only where odours are noticed.
- **Formaldehyde** only where odours are noticed.
- **Lighting** levels at the same locations.
- **Supply and return airflow** at the same locations.
- ***Air Pressurization** (positive or negative) at the same locations.

Note:
1. No water damage/mould or visible dust inspection is required for BOMA IAQ testing)

Appendix D:

Government of Alberta, August 8, Alberta Infrastructure, Revised BOMA IAQ Assessment Guide

<u>BOMA IAQ testing</u>: (as of 2013.08.08)

Test 10 – 30 <u>occupied</u> areas in a 1 to 4 storey building (depending on size), or 4 – 6 <u>occupied</u> areas per floor in a high-rise building (greater than 4 floors).

Morning and afternoon spot tests are to be taken to capture possible variances. Afternoon spot tests to include only temperature, relative humidity, carbon dioxide and carbon monoxide. No long term testing is required.

Note the outdoor weather conditions and perform outdoor tests (morning and afternoon) for temperature, relative humidity, carbon dioxide and carbon monoxide.

<u>Perform the following indoor tests:</u>

- **Temperature**, **relative humidity**, **carbon dioxide** and **carbon monoxide**, ensuring all floors and air systems are tested.
- **Ambient dust** at the same locations.
- **Total volatile organic compounds** (**TVOC's**) <u>only</u> where odours are noticed.
- **Formaldehyde** <u>only</u> where odours are noticed.
- **Lighting** levels (Stefan Bernath will conduct tests).
- **Supply and return airflow** at the same locations.
- **Air Pressurization** (positive or negative) <u>only</u> at locations where contaminates are present.

<u>Note</u>:

1. No water damage/mould or visible dust inspections are required for BOMA IAQ testing.

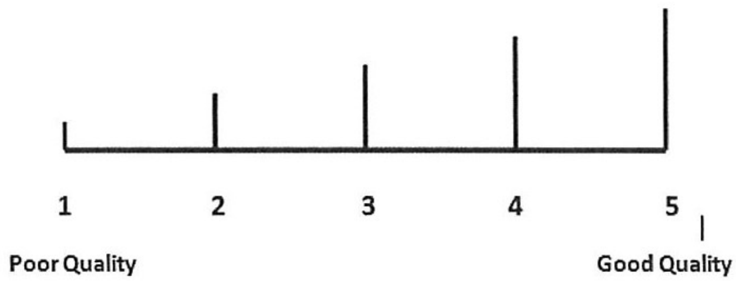
Appendix E:

Ncube and Riffat, 2012, Indoor Air Quality Questionnaire

The Indoor Environment Quality Questionnaire	September 20--
	The Indoor Environment Quality Questionnaire

Question 2 – The Indoor Environment

2 (b) How would you rate the quality of Indoor Environment in your work area **AT THIS MOMENT**? (Please mark anywhere on the assessment scales below; from 1 to 5)



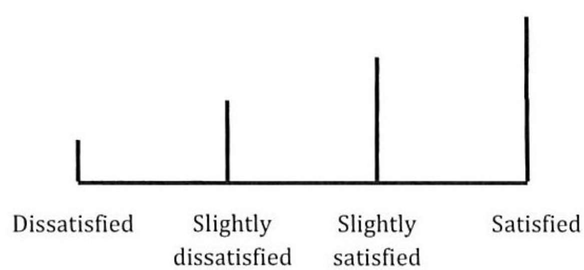
Question 3 – Thermal Environment

How would you rate your thermal sensation in your work area **AT THIS MOMENT**? (Please mark your answer on the assessment scale below)

Cold	Cool	Slightly Cool	Neutral	Slightly Warm	Warm	Hot
-3	-2	-1	0	+1	+2	+3

Question 4 – Level of Environment Control

How satisfied are you with your level of control of comfort parameters at your workspace **AT THIS MOMENT**? E.g. opening or closing a window or a door to the outside, adjusting a thermostat, drapes or blinds, space heater, turning local fan on or off? (Please mark anywhere on the assessment scale below)

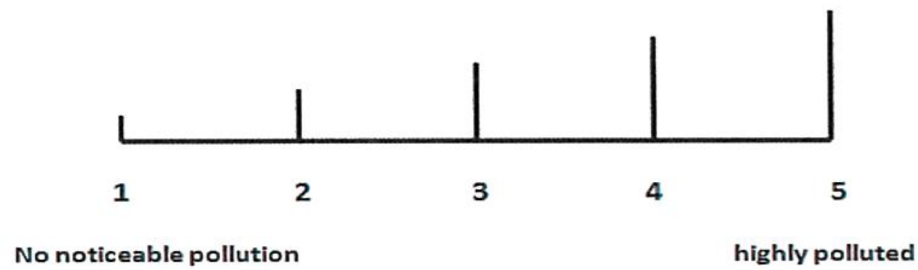


Question 7 - Indoor Air Quality

(a) How would you perceive the air quality in your work environment **AT THIS MOMENT**? (Please mark anywhere on the assessment scale below; from 1 to 5)

Not Acceptable (1) : : : : : : : :2 : : : : : : : : ::3 : : : : : : : : : : :4 : : : : : : : : : : : : (5) **Acceptable**

(b) How would you describe the levels of air pollution you perceive in your work environment right now? (Please mark your answer on the assessment scale given):



(c) Are you experiencing any of the following symptoms **AT THIS MOMENT?** (Please tick the scales below at the place that best represents how you feel at this moment)

Blocked nose |————————————| **Clear nose**

Dry nose |————————————| **Runny nose**

Dry throat |————————————| **Not dry throat**

Dry mouth |————————————| **Not dry mouth**

Question 8 - Local Discomfort factors

AT THIS MOMENT do you feel any discomfort caused by any of the following in your work area? Please tick where applicable.

Draughts – cold or warm draughts	
Cold floors	
Cold equipment	
Vertical Air Temperature Varies (e.g. from head to heels)	
Discomfort due to differences in radiant heat? e.g. radiators or other heat emitters or surfaces	

Q4. Further comments on the building's comfort level are welcomed in the box below. If you wish to elaborate on any of the issues raised in this questionnaire then please refer to the section and question number.

Additional Information:

End of Questionnaire! Thank You for your participation.

Appendix F:

ASHRAE, 2013, Standard 55-2013, Metabolic Rates for Typical Tasks

Activity	Metabolic Rate		
	Met Units	W/m^2	$Btu/h \cdot ft^2$
Resting			
Sleeping	0.7	40	13
Reclining	0.8	45	15
Seated, quiet	1.0	60	18
Standing, relaxed	1.2	70	22
Walking (on level surface)			
0.9 m/s, 3.2 km/h, 2.0 mph	2.0	115	37
1.2 m/s, 4.3 km/h, 2.7 mph	2.6	150	48
1.8 m/s, 6.8 km/h, 4.2 mph	3.8	220	70
Office Activities			
Reading, seated	1.0	55	18
Writing	1.0	60	18
Typing	1.1	65	20
Filing, seated	1.2	70	22
Filing, standing	1.4	80	26
Walking about	1.7	100	31
Lifting/packing	2.1	120	39
Driving/Flying			
Automobile	1.0–2.0	60–115	18–37
Aircraft, routine	1.2	70	22
Aircraft, instrument landing	1.8	105	33
Aircraft, combat	2.4	140	44
Heavy vehicle	3.2	185	59
Miscellaneous Occupational Activities			
Cooking	1.6–2.0	95–115	29–37
House cleaning	2.0–3.4	115–200	37–63
Seated, heavy limb movement	2.2	130	41
Machine work			
sawing (table saw)	1.8	105	33
light (electrical industry)	2.0–2.4	115–140	37–44
heavy	4.0	235	74
Handling 50 kg (100 lb) bags	4.0	235	74
Pick and shovel work	4.0–4.8	235–280	74–88
Miscellaneous Leisure Activities			
Dancing, social	2.4–4.4	140–255	44–81
Calisthenics/exercise	3.0–4.0	175–235	55–74
Tennis, single	3.6–4.0	210–270	66–74
Basketball	5.0–7.6	290–440	90–140
Wrestling, competitive	7.0–8.7	410–505	130–160

Appendix G:

ASHRAE, 2013b, Standard 55-2013, Clothing and Garment Insulation Values

Clothing Description	Garments Included*	I_{cl} (clo)
Trousers	1) Trousers, short-sleeve shirt	0.57
	2) Trousers, long-sleeve shirt	0.61
	3) #2 plus suit jacket	0.96
	4) #2 plus suit jacket, vest, T-shirt	1.14
	5) #2 plus long-sleeve sweater, T-shirt	1.01
	6) #5 plus suit jacket, long underwear bottoms	1.30
Skirts/Dresses	7) Knee-length skirt, short-sleeve shirt (sandals)	0.54
	8) Knee-length skirt, long-sleeve shirt, full slip	0.67
	9) Knee-length skirt, long-sleeve shirt, half slip, long-sleeve sweater	1.10
	10) Knee-length skirt, long-sleeve shirt, half slip, suit jacket	1.04
	11) Ankle-length skirt, long-sleeve shirt, suit jacket	1.10
Shorts	12) Walking shorts, short-sleeve shirt	0.36
Overalls/Coveralls	13) Long-sleeve coveralls, T-shirt	0.72
	14) Overalls, long-sleeve shirt, T-shirt	0.89
	15) Insulated coveralls, long-sleeve thermal underwear tops and bottoms	1.37
Athletic	16) Sweat pants, long-sleeve sweatshirt	0.74
Sleepwear	17) Long-sleeve pajama tops, long pajama trousers, short 3/4 length robe (slippers, no socks)	0.96

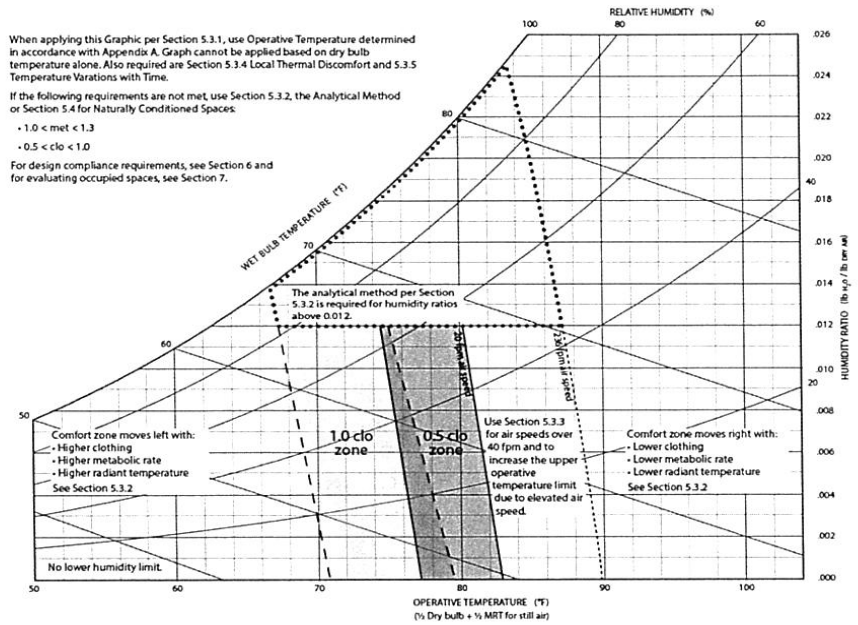
* All clothing ensembles, except where otherwise indicated in parentheses, include shoes, socks, and briefs or panties. All skirt/dress clothing ensembles include panty hose and no additional socks.

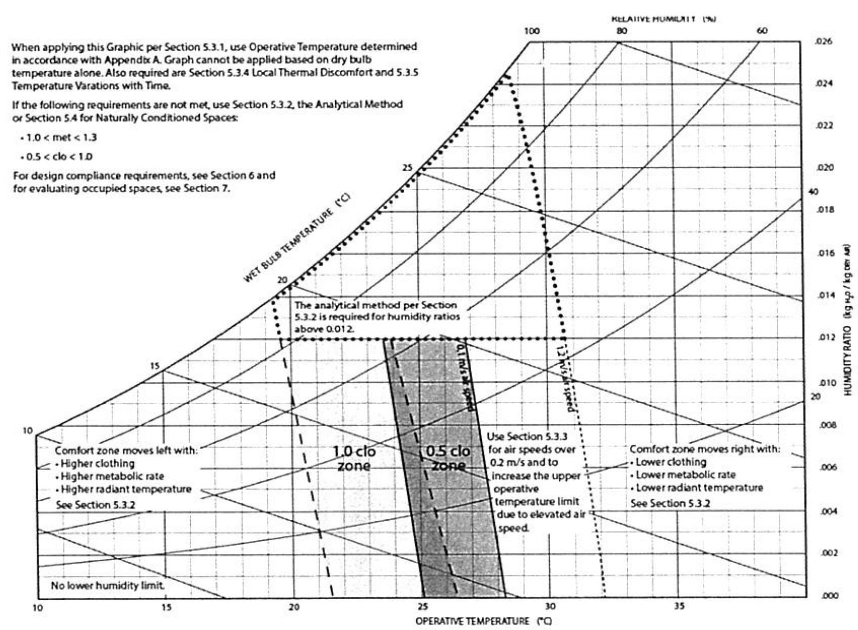
Garment Description[a]	I_{clu}(clo)	Garment Description[a]	I_{clu}(clo)
Underwear		Dress and Skirts[b]	
Bra	0.01	Skirt (thin) mm	0.14
Panties	0.03	Skirt (thick)	0.23
Men's briefs	0.04	Sleeveless, scoop neck (thin)	0.23
T-shirt	0.08	Sleeveless, scoop neck (thick), i.e., jumper	0.27
Half-slip	0.14	Short-sleeve shirtdress (thin)	0.29
Long underwear bottoms	0.15	Long-sleeve shirtdress (thin)	0.33
Full slip	0.16	Long-sleeve shirtdress (thick)	0.47
Long underwear top	0.20	Sweaters	
Footwear		Sleeveless vest (thin)	0.13
Ankle-length athletic socks	0.02	Sleeveless vest (thick)	0.22
Panty hose/stockings	0.02	Long-sleeve (thin)	0.25
Sandals/thongs	0.02	Long-sleeve (thick)	0.36
Shoes	0.02	Suit Jackets and Vests[c]	
Slippers (quilted, pile lined)	0.03	Sleeveless vest (thin)	0.10
Calf-length socks	0.03	Sleeveless vest (thick)	0.17
Knee socks (thick)	0.06	Single-breasted (thin)	0.36
Boots	0.10	Single-breasted (thick)	0.44
Shirts and Blouses		Double-breasted (thin)	0.42
Sleeveless/scoop-neck blouse	0.12	Double-breasted (thick)	0.48
Short-sleeve knit sport shirt	0.17	Sleepwear and Robes	
Short-sleeve dress shirt	0.19	Sleeveless short gown (thin)	0.18
Long-sleeve dress shirt	0.25	Sleeveless long gown (thin)	0.20
Long-sleeve flannel shirt	0.34	Short-sleeve hospital gown	0.31
Long-sleeve sweatshirt	0.34	Short-sleeve short robe (thin)	0.34
Trousers and Coveralls		Short-sleeve pajamas (thin)	0.42
Short shorts	0.06	Long-sleeve long gown (thick)	0.46
Walking shorts	0.08	Long-sleeve short wrap robe (thick)	0.48
Straight trousers (thin)	0.15	Long-sleeve pajamas (thick)	0.57
Straight trousers (thick)	0.24	Long-sleeve long wrap robe (thick)	0.69
Sweatpants	0.28		
Overalls	0.30		
Coveralls	0.49		

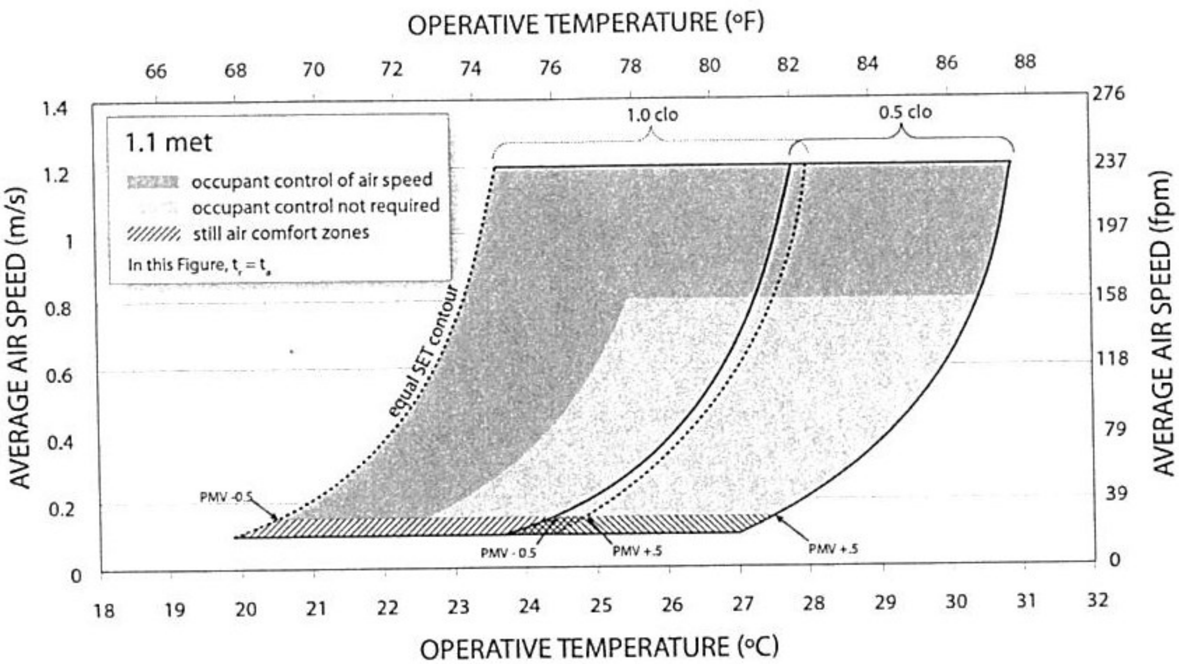
a. "Thin" refers to garments made of lightweight, thin fabrics often worn in the summer; "thick" refers to garments made of heavyweight, thick fabrics often worn in the winter.
b. Knee-length dresses and skirts.
c. Lined vests.

Appendix H:

ASHRAE, 2013b, Standard 55-2013, Graphical Representation of Comfort Zone and Acceptable Ranges of Operator Temperature and Average Air Speed







OPERATIVE TEMPERATURE (°F)
66
68
70
72
74
76
78
80
82
84
86
88
1.4
1.2
1
0.8
0.6
0.4
0.2
0
276
237
197
158
118
79
39
0
AVERAGE AIR SPEED (m/s)
AVERAGE AIR SPEED (fpm)
1.1 met
occupant control of air speed
occupant control not required
still air comfort zones
In this Figure, $t_r = t_a$
1.0 clo
0.5 clo
equal SET contour
PMV -0.5
PMV - 0.5
PMV +.5
PMV +.5
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
OPERATIVE TEMPERATURE (°C)

Appendix I:

ASHRAE, 2013a, Standard 62.1-2013, Table B-1

	Enforceable and/or Regulatory Levels			Nonenforced Guidelines and Reference Levels			
	NAAQS/EPA (Ref. B-4)	OSHA (Ref. B-5)	MAK (Ref. B-2)	Canadian (Ref. B-8)	WHO/Europe (Ref. B-11)	NIOSH (Ref. B-13)	ACGIH (Ref. B-1)
Carbon dioxide		5000 ppm	5000 ppm 10,000 ppm [1 h]	3500 ppm [L]		5000 ppm 30,000 ppm [15 min]	5000 ppm 30,000 ppm [15 min]
Carbon monoxide[c]	9 ppm [g] 35 ppm [1 h] [g]	50 ppm	30 ppm 60 ppm [30 min]	11 ppm [8 h] 25 ppm [1 h]	90 ppm [15 min] 50 ppm [30 min] 25 ppm [1 h] 10 ppm [8 h]	35 ppm 200 ppm [C]	25 ppm
Formaldehyde[h]		0.75 ppm 2 ppm [15 min]	0.3 ppm 1 ppm[i]	0.1 ppm [L] 0.05 ppm [L] [b]	0.1 mg/m^3 (0.081 ppm) [30 min][p]	0.016 ppm 0.1 ppm [15 min]	0.3 ppm [C]
Lead	1.5 $\mu g/m^3$ [3 months]	0.05 mg/m^3	0.1 mg/m^3 1 mg/m^3 [30 min]	Minimize exposure	0.5 $\mu g/m^3$ [1 yr]	0.050 mg/m^3	0.05 mg/m^3
Nitrogen dioxide	0.05 ppm [1 yr]	5 ppm [C]	5 ppm 10 ppm [5 min]	0.05 ppm 0.25 ppm [1 h]	0.1 ppm[1 h] 0.02 ppm [1 yr]	1 ppm [15 min]	3 ppm 5 ppm [15 min]
Ozone	0.12 ppm [1 h][g] 0.08 ppm	0.1 ppm	j	0.12 ppm [1 h]	0.064 ppm (120 $\mu g/m^3$) [8 h]	0.1 ppm [C]	0.05 ppm[k] 0.08 ppm[l] 0.1 ppm[m] 0.2 ppm[n]
Particles[e] <2.5 µm MMAD[d]	15 $\mu g/m^3$[1 yr][o] 35 $\mu g/m^3$ [24 h][o]	5 mg/m^3	1.5 mg/m^3 for <4 µm	0.1 mg/m^3 [1 h] 0.040 mg/m^3 [L]			3 mg/m^3 [C]
Particles[e] <10 µm MMAD[d]	150 $\mu g/m^3$ [24 h][o]		4 mg/m^3				10 mg/m^3 [C]
Radon				800 Bq/m^3 [1 yr]			
Sulfur dioxide	0.03 ppm [1 yr] 0.14 ppm [24 h][g]	5 ppm	0.5 ppm 1 ppm [i]	0.38 ppm [5 min] 0.019 ppm	0.048 ppm [24 h] 0.012 ppm [1 yr]	2 ppm 5 ppm [15 min]	2 ppm 5 ppm [15 min]
Total Particles[e]		15 mg/m^3					

a. Numbers in brackets [ ] refer to either a ceiling or to averaging times of less than or greater than eight hours (min = minutes; h = hours; y = year; C = ceiling, L = long-term). Where no time is specified, the averaging time is eight hours.

b. Target level is 0.05 ppm because of its potential carcinogenic effects. Total aldehydes limited to 1 ppm. Although the epidemiological studies conducted to date provide little convincing evidence that formaldehyde is carcinogenic in human populations, because of this potential, indoor levels should be reduced as much as possible.

c. As one example regarding the use of values in this table, readers should consider the applicability of carbon monoxide concentrations. The concentrations considered acceptable for nonindustrial, as opposed to industrial, exposure are substantially lower. These lower concentrations (in other words, the ambient air quality standards, which are required to consider populations at highest risk) are set to protect the most sensitive subpopulation, individuals with pre-existing heart conditions.

d. MMAD = mass median aerodynamic diameter in microns (micrometers). Less than 3.0 µm is considered respirable; less than 10 µm is considered inhalable.

e. Nuisance particles not otherwise classified (PNOC), not known to contain significant amounts of asbestos, lead, crystalline silica, known carcinogens, or other particles known to cause significant adverse health effects.

f. See Table B-2 for the U.S. EPA guideline.

g. Not to be exceeded more than once per year

h. The U.S. Department of Housing and Urban Development adopted regulations concerning formaldehyde emissions from plywood and particleboard intended to limit the airborne concentration of formaldehyde in manufactured homes to 0.4 ppm. (24 CFR Part 3280, HUD Manufactured Home Construction and Safety Standards). In addition, California Air Resources Board Regulation §93120, entitled "Airborne Toxic Control Measure to Reduce Formaldehyde Emissions from Composite Wood Products" has specific chamber-based requirements for composite wood products sold in California. [B-47]

i. Never to be exceeded

j. Carcinogen, no maximum values established

k. TLV® for heavy work

l. TLV® for moderate work

m. TLV® for light work

n. TLV® for heavy, moderate, or light workloads (less than or equal to two hours)

o. 62FR38652 - 38760, July 16, 1997

p. Epidemiological studies suggest a causal relationship between exposure to formaldehyde and nasopharyngeal cancer, although the conclusion is tempered by the small numbers of observed and expected cases. There are also epidemiological observations of an association between relatively high occupational exposures to formaldehyde and sinonasal cancer.

Appendix J:

ASHRAE, 2013a, Standard 62.1-2013, Table B-2

The substances listed in Table B-2 are common air contaminants of concern in nonindustrial environments. The target concentrations that have been set or proposed by various national or international organizations concerned with health and comfort effects of outdoor and indoor air are listed for reference only. The table is not inclusive of all contaminants in indoor air, and achieving the target indoor concentrations for all of the listed substances does not ensure freedom from sensory irritation or from all adverse health effects for all occupants. In addition to indoor contaminant levels, the acceptability of indoor air also involves thermal conditions, indoor moisture levels as they impact microbial growth, and other indoor environmental factors. ASHRAE is not selecting or recommending default concentrations.

Health or comfort effects and exposure periods that are the basis for the guideline levels are listed in the "comments" column. For design, the goal should be to meet the guideline levels continuously during occupancy because people spend the great majority of their time indoors.

Users of this table should recognize that unlisted noxious contaminants can also cause unacceptable IAQ with regard to comfort (sensory irritation), odors, and health. When such contaminants are known or might reasonably be expected to be present, selection of an acceptable concentration and exposure may require reference to other guidelines or a review and evaluation of relevant toxicological and epidemiological literature. (Table B-2 summarizes some of this literature.)

TABLE B-2 Concentration of Interest for Selected Contaminants

(Note: References numbers that are followed by [c] and [m] list the concentrations of interest [c] and measurement methods [m].)

TABLE 2.3.1 (Note: The user of any value in this table should take into account the purpose for which it was adopted and the means by which it was developed.)

Contaminant	Sources	Concentrations of Interest	Comments	References
Carbon Monoxide (CO)	Leaking vented combustion appliances Unvented combustion appliances Parking garages Outdoor air	9 ppm (8 h)	Based on effects on persons with coronary artery disease, average exposure for eight hours. Sustained indoor concentrations exceeding outdoor concentrations may merit further investigation. Many carbon monoxide measuring instruments have limited accuracy at low levels. Sources—burning of gasoline, natural gas, coal, oil, etc. (Note: CO is unlikely to be the only contaminant of concern in parking garages or other spaces where vehicles operate.) Health effects—reduces ability of blood to bring oxygen to body cells and tissues; cells and tissues need oxygen to work. Carbon monoxide may be particularly hazardous to people who have heart or circulatory problems and people who have damaged lungs or breathing passages.	B-4 [c] B-9 [m]
Formaldehyde (HCHO)	Pressed-wood products Furniture and furnishings	0.1 mg/m^3 (0.081 ppm) (30 min)	Based on irritation of sensitive people, 30-minute exposure (WHO)	B-11 [c] B-9, 26 [m]
		27 ppb (8 h)	Established as a never-to-exceed guideline to avoid irritant effects in sensitive individuals. Does not protect against formaldehyde's potential carcinogenicity (California Air Resources Board).	B-16
		45 ppb (55 $\mu g/m^3$) (1 h) 7.3 ppb (9 $\mu g/m^3$) (8 h)	Acute and 8-hour noncancer Reference Exposure Levels (RELs) developed based on current scientific database (Cal-EPA, OEHHA).	B-36
			Health effects—Acute and chronic inhalation exposure to formaldehyde in humans can result in eye, nose, and throat irritation, respiratory symptoms, exacerbation of asthma, and sensitization. Human studies have reported an association between formaldehyde exposure and lung and nasopharyngeal cancer. In 2004, the International Agency for Research on Cancer (IARC) concluded that "*formaldehyde is carcinogenic to humans (Group 1)*, on the basis of *sufficient evidence* in humans and *sufficient evidence* in experimental animals."	B-19, 20, 36, 40
		16 ppb	FEMA Procurement Specification for Mobile Homes	B-48

[a] The US EPA has promulgated a guideline value of 4 pCi/L indoor concentration. This is not a regulatory value but an action level where mitigation is recommended if the value is exceeded in long-term tests.

Conversion Factors[B-17]

Parts per million and mass per unit volume:

Measurements of indoor airborne concentrations of substances are generally converted to standard conditions of 77°F (25°C) and 29.92 in. Hg (101.325 kPa) pressure. Vapors or gases are often expressed in parts per million (ppm) by volume or in mass per unit volume. Concentrations in ppm by volume can be converted to mass per unit volume values as follows:

ppm × molecular weight/24,450 = mg/L
ppm × molecular weight/0.02445 = $\mu g/m^3$
ppm × molecular weight/24.45 = mg/m^3
ppm × molecular weight × 28.3/24,450 = mg/ft^3

Contaminant	Sources	Concentrations of Interest	Comments	References
Lead (Pb)	Paint dust Outdoor air	1.5 μg/m^3	Based on adverse effects on neuropsychological functioning of children, average exposure for three months (WHO: 0.5–1 μg/m^3 for 1 year). Sources—leaded gasoline (being phased out), paint (houses, cars), smelters (metal refineries), manufacture of lead storage batteries. Health effects—brain and other nervous system damage; children are at special risk. Some lead-containing chemicals cause cancer in animals. Lead causes digestive and other health problems. Environmental effects—Lead can harm wildlife.	B-4 [c] B-4 [m] B-18
Nitrogen Dioxide (NO_2)	Leaking vented combustion appliances Unvented combustion appliances Outdoor air Parking garages	100 μg/m^3	Based on providing protection against adverse respiratory effects, average exposure for one year.	B-4 [c] B-9 [m] B-18
			Sources—burning of gasoline, natural gas, coal, oil, etc. Cars are an important source of NO_2 outdoors and cooking and water- and space-heating devices are important sources indoors. Health effects—lung damage, illnesses of breathing passages and lungs (respiratory system). Environmental effects—Nitrogen dioxide is a component of acid rain (acid aerosols), which can damage trees and lakes. Acid aerosols can reduce visibility. Property damage—Acid aerosols can eat away stone used on buildings, statues, monuments, etc.	
		470 μg/m^3	24-hour average to prevent high exposures during use of combustion appliances such as space-heating devices and gas stoves.	B-41
Odors	Occupants VOC sources (including fungal sources such as mold) Cooking, food processing, sewage, biowaste facilities, etc.	Predicted (or measured) acceptability to 80% or more of occupants or visitors	CO_2 concentration can be used as a surrogate for occupant odors (odorous bioeffluents). See Appendix C for a discussion of indoor CO_2 levels and ventilation rates. For sources other than people, source control is recommended.	B-12, 24, 29, 30 [c] B-9 (CO_2), B-15 (odor) [m]
Ozone (O_3)	Electrostatic appliances Office machines Ozone generators Outdoor air	100 μg/m^3 (50 ppb)	Based on 25% increase in symptom exacerbations among adults or asthmatics (normal activity), eight-hour exposure (WHO); continuous exposure (FDA). Ozone present at levels below the concentration of interest may contribute to the degradation of indoor air quality directly and by reacting with other contaminants in the indoor space. Ground-level ozone is the principal component of smog. Sources—outdoors, from chemical reaction of pollutants, VOCs, and NO_x; indoors, from photocopiers, laser printers, ozone generators, electrostatic precipitators, and some other air cleaners. Health effects—breathing problems, reduced lung function, asthma, irritated eyes, stuffy nose, reduced resistance to colds and other infections. May speed up aging of lung tissue. Environmental effects—Outdoors, ozone can damage plants and trees; smog can cause reduced visibility. Property damage—Indoors and outdoors, ozone damages natural and synthetic rubbers, plastics, fabrics, etc.	B-6, 11 [c] B-6 [m] B-18
Particles ($PM_{2.5}$)	Combustion products, cooking, candles, incense, resuspension, outdoor air, diesel exhaust, and parking garages	15 μg/m^3		B-4

[a] The US EPA has promulgated a guideline value of 4 pCi/L indoor concentration. This is not a regulatory value but an action level where mitigation is recommended if the value is exceeded in long-term tests.

Conversion Factors[B-17]

Parts per million and mass per unit volume:

Measurements of indoor airborne concentrations of substances are generally converted to standard conditions of 77°F (25°C) and 29.92 in. Hg (101.325 kPa) pressure. Vapors or gases are often expressed in parts per million (ppm) by volume or in mass per unit volume. Concentrations in ppm by volume can be converted to mass per unit volume values as follows:

- ppm × molecular weight/24,450 = mg/L
- ppm × molecular weight/0.02445 = μg/m^3
- ppm × molecular weight/24.45 = mg/m^3
- ppm × molecular weight × 28.3/24,450 = mg/ft^3

Contaminant	Sources	Concentrations of Interest	Comments	References
Particles (PM_{10})	Dust Smoke Deteriorating materials Outdoor air	50 μg/m³	Based on protecting against respiratory morbidity in the general population and avoiding exacerbation of asthma, average exposure for one year, no carcinogens. Indoor concentrations are normally lower; guideline level may lead to unacceptable deposition of "dust."	B-4 [c] B-4 [m]
			Sources—burning of wood, diesel, and other fuels; industrial plants; agriculture (plowing, burning off fields); unpaved roads. Health effects—nose and throat irritation, lung damage, bronchitis, early death. Environmental effects—Particulates are the main source of haze that reduces visibility.	
			Property damage—Ashes, soot, smoke, and dust can dirty and discolor structures and other property, including clothes and furniture.	B-18
Radon (Rn)	Soil gas	4 pCi/L[a]	Based on lung cancer, average exposure for one year.	B-7 [c,m] B-10 [m]
Sulfur Dioxide (SO_2)	Unvented space heaters (kerosene) Outdoor air	80 μg/m³	Based on protecting against respiratory morbidity in the general population and avoiding exacerbation of asthma, average exposure for one year (WHO: 50 μg/m³ if with PM). Source—burning of coal and oil, especially high-sulfur coal from the eastern United States; industrial processes (paper, metals). Health effects—breathing problems; may cause permanent damage to lungs. Environmental effects—SO_2 is a component of acid rain (acid aerosols), which can damage trees and lakes. Acid aerosols can also reduce visibility. Property damage—Acid aerosols can eat away stone used in buildings, statues, monuments, etc.	B-4 [c] B-4 [m] B-18
Total Volatile Organic Compounds (TVOCs)	New building materials and furnishings Consumable products Maintenance materials Outdoor air	Precise guidance on TVOC concentrations cannot be given	A variety of definitions of TVOC have been employed in the past. Reference B-27 contains a specific definition that reflects recent thinking on the subject. There is insufficient evidence that TVOC measurements can be used to predict health or comfort effects. In addition, odor and irritation responses to organic compounds are highly variable. Furthermore, no single method currently in use measures all organic compounds that may be of interest. Therefore, some investigators have reported the total of all measured VOCs as the SumVOC in order to make explicit that the reported value does not represent the total of all VOCs present. Some of the references included here use this method for presenting VOC measurement results. Setting target concentrations for TVOCs is not recommended. Setting target concentrations for specific VOCs of concern is preferred.	B-9 [m] B-14, 26-28, 35, 37
Volatile Organic Compounds (VOCs) (See Table B-3 for a list of selected compounds)	New building materials and furnishings Consumable products Maintenance materials Outdoor air Parking garages Refueling stations	Must be determined for each individual compound (See Table B-3 for a list of selected compounds)	Individual volatile organic compounds may be contaminants of concern in the application of the IAQ Procedure. Concentrations of concern range from less than 1 part per billion (ppb) for some very toxic compounds or for compounds having very low odor thresholds up to concentrations several orders of magnitude higher. Not all compounds can be identified, and toxicological data are incomplete for many compounds.	B-22–26, 28, 42, 43, 44 [c] B-9, 10, 21 [m] B-11, 15, 36, 38, 39, 11

[a] The US EPA has promulgated a guideline value of 4 pCi/L indoor concentration. This is not a regulatory value but an action level where mitigation is recommended if the value is exceeded in long-term tests.

Conversion Factors[B-17]

Parts per million and mass per unit volume:

Measurements of indoor airborne concentrations of substances are generally converted to standard conditions of 77°F (25°C) and 29.92 in. Hg (101.325 kPa) pressure. Vapors or gases are often expressed in parts per million (ppm) by volume or in mass per unit volume. Concentrations in ppm by volume can be converted to mass per unit volume values as follows:

$ppm \times molecular\ weight/24{,}450 = mg/L$

$ppm \times molecular\ weight/0.02445 = \mu g/m^3$

$ppm \times molecular\ weight/24.45 = mg/m^3$

$ppm \times molecular\ weight \times 28.3/24{,}450 = mg/ft^3$

Appendix K:

ASHRAE, 2013a, Standard 62.1-2013, Table B-3

Table B-3 provides information that may be beneficial for designers who choose to comply with the Indoor Air Quality Procedure of this Standard. The VOCs included in the table were reported in published, peer-reviewed surveys conducted in office buildings and in new and existing residences in North America during the period 1990–2000.[B-42,B-43,B-45] Only those VOCs for which exposure guidelines for the general population have been developed by cognizant authorities are listed in Table B-3.

Reference Exposure Levels (RELs) are guidelines for acute, 8-hour and chronic inhalation exposures developed by California Office of Health Hazard Assessment (OEHHA). Minimal Risk Levels (MRLs) for hazardous substances are guidelines for acute, intermediate and chronic inhalation exposures developed by the Agency for Toxic Substances and Disease Registry (ATSDR). Factors for $\mu g/m^3$ to ppb concentration conversions are shown.

The table does not purport to represent (a) all possible chemicals found in nonindustrial indoor environments and (b) all concentration guidelines, standards, and regulatory limits. Published, peer-reviewed surveys conducted in office buildings and in new and existing residences in North America since 2000 may identify several more compounds, for some of which guidelines may be available from the cognizant authorities described above.

TABLE B-3 Concentrations of Interest for Selected Volatile Organic Compounds

Compound	CAS Number	Chemical Class[a]	Conversion Factor: $\mu g/m^3$ to ppb[b]	CA OEHHA REL[B-36]			ATSDR MRL[B-46]		
				Acute[c] ($\mu g/m^3$)	8-hr[d] ($\mu g/m^3$)	Chronic[e] ($\mu g/m^3$)	Acute[f] (ppb)	Intermediate[g] (ppb)	Chronic[h] (ppb)
Acetaldehyde	75-07-0	Ald	0.554	470	300	140			
Acrolein	107-02-8	Ald	0.436	2.5	0.7	0.35	3	0.4	
Acrylonitrile	107-13-1	Misc	0.460			5	100		
Benzene	71-43-2	Arom	0.313	1300		60	9	6	3
Bromomethane (Methyl bromide)	74-83-9	Halo	0.258				50	50	5
1,3-Butadiene	106-99-0	Alke	0.452			20			
2-Butanone	78-93-3	Ket	0.339	13,000					
2-Butoxyethanol	111-76-2	Gly	0.207				6000	3000	200
t-Butyl methyl ether (Methyl-*t*-butyl ether)	1634-04-4	Ethr	0.277			8000	2000	700	700
Carbon disulfide	75-15-0	Misc	0.321	6200		800			300
Carbon tetrachloride	56-23-5	Halo	0.159	1900		40		30	30
Chlorobenzene	108-90-7	ClAro	0.217			1000			
Chloroform	67-66-3	Halo	0.205	150		300	100	50	20

a. Alc = alcohol; Ethr = ether; Gly = glycol ether; Ket = ketone; Ald = aldehyde; Estr = acetates and other esters; Acid = carboxylic acid; Alka = alkane HC; Alke = alkene HC; Cycl = cyclic HC; Terp = terpene HC; Arom = aromatic HC; ClAro = chlorinated aromatic HC; Halo = halogenated aliphatic HC; Misc = miscellaneous category
b. Conversion factors from $\mu g/m^3$ to ppb
c. Exposure averaging time is 1 hour
d. Exposure averaging time is 8 hours and which may be repeated
e. Designed to address continuous exposures for up to a lifetime: the exposure metric used is the annual average exposure
f. Exposure to a chemical for a duration of 14 days or less, as specified in the toxicological profiles
g. Exposure to a chemical for a duration of 15–364 days, as specified in the toxicological profiles
h. Exposure to a chemical for 365 days or more, as specified in the toxicological profiles
i. See also Tables B-1 and B-2 for additional guidance on formaldehyde.

Compound	CAS Number	Chemical Class[a]	Conversion Factor: $\mu g/m^3$ to ppb[b]	CA OEHHA REL[B-36] Acute[c] ($\mu g/m^3$)	CA OEHHA REL[B-36] 8-hr[d] ($\mu g/m^3$)	CA OEHHA REL[B-36] Chronic[e] ($\mu g/m^3$)	ATSDR MRL[B-46] Acute[f] (ppb)	ATSDR MRL[B-46] Intermediate[g] (ppb)	ATSDR MRL[B-46] Chronic[h] (ppb)
1,4-Dichlorobenzene	106-46-7	ClAro	0.166			800	2000	200	10
1,2-Dichloroethane (Ethylene dichloride)	107-06-2	Halo	0.247						600
Dichloromethane (Methylene chloride)	75-09-2	Halo	0.288	14,000		400	600	300	300
1,4-Dioxane	123-91-1	Ethr	0.278	3000		3000	2000	1000	1000
Ethylbenzene	100-41-4	Arom	0.230			2000	10,000	700	300
Ethylene glycol	107-21-1	Gly	0.394			400	788		
Formaldehyde[i]	50-00-0	Ald	0.815	55	9	9	40	30	8
n-Hexane	110-54-3	Alka	0.284			7000	600		
Naphthalene	91-20-3	Arom	0.191			9			0.7
Phenol	108-95-2	Alc	0.260	5800		200			
2-Propanol (Isopropanol)	67-63-0	Alc	0.407	3200		7000			
2-Propanone (Acetone)	67-64-1	Ket	0.421				26,000	13,000	13,000
Styrene	100-42-5	Arom	0.235	21,000		900	2000		200
Tetrachloroethene (Tetrachloroethylene, Perchloroethylene)	127-18-4	Halo	0.147	20,000		35	200		40
Toluene	108-88-3	Arom	0.265	37,000		300	1000		80
1,1,1-Trichloroethane (Methyl chloroform)	71-55-6	Halo	0.183	68,000		1000	2000	700	
Trichloroethene (Trichloroethylene)	79-01-6	Halo	0.186			600	2000	100	
Vinyl chloride	75-01-4	Halo	0.391	180,000			500	30	
Xylene isomers	1330-20-7	Arom	0.230	22,000		700	2000	600	50

a. Alc = alcohol; Ethr = ether; Gly = glycol ether; Ket = ketone; Ald = aldehyde; Estr = acetates and other esters; Acid = carboxylic acid; Alka = alkane HC; Alke = alkene HC; Cycl = cyclic HC; Terp = terpene HC; Arom = aromatic HC; ClAro = chlorinated aromatic HC; Halo = halogenated aliphatic HC; Misc = miscellaneous category
b. Conversion factors from $\mu g/m^3$ to ppb
c. Exposure averaging time is 1 hour
d. Exposure averaging time is 8 hours and which may be repeated
e. Designed to address continuous exposures for up to a lifetime: the exposure metric used is the annual average exposure
f. Exposure to a chemical for a duration of 14 days or less, as specified in the toxicological profiles
g. Exposure to a chemical for a duration of 15–364 days, as specified in the toxicological profiles
h. Exposure to a chemical for 365 days or more, as specified in the toxicological profiles
i. See also Tables B-1 and B-2 for additional guidance on formaldehyde.

Appendix L:

ASHRAE, 2009, Indoor Air Quality Guide, Best Practice for Design, Construction and Commissioning, Table of Contents

CONTENTS

Acknowledgments VIII

Abbreviations and Acronyms X

Foreword: Why this Guide Was Written XII

Message to Building Owners XIII

Introduction XIV

PART I—Summary Guidance 1

Overview Information for Design, Construction, and Commissioning for IAQ 1

Objective 1 – Manage the Design and Construction Process to Achieve Good IAQ 2
Strategy 1.1 – Integrate Design Approach and Solutions 4
Strategy 1.2 – Commission to Ensure that the Owner's IAQ Requirements are Met 8
Strategy 1.3 – Select HVAC Systems to Improve IAQ and Reduce the Energy Impacts of Ventilation 12
Strategy 1.4 – Employ Project Scheduling and Manage Construction Activities to Facilitate Good IAQ 16
Strategy 1.5 – Facilitate Effective Operation and Maintenance for IAQ 19

Objective 2 – Control Moisture in Building Assemblies 23
Strategy 2.1 – Limit Penetration of Liquid Water into the Building Envelope 25
Strategy 2.2 – Limit Condensation of Water Vapor within the Building Envelope and on Interior Surfaces 29
Strategy 2.3 – Maintain Proper Building Pressurization 33
Strategy 2.4 – Control Indoor Humidity 37
Strategy 2.5 – Select Suitable Materials, Equipment, and Assemblies for Unavoidably Wet Areas 43
Strategy 2.6 – Consider Impacts of Landscaping and Indoor Plants on Moisture and Contaminant Levels 46

Objective 3 – Limit Entry of Outdoor Contaminants 49
Strategy 3.1 – Investigate Regional and Local Outdoor Air Quality 51
Strategy 3.2 – Locate Outdoor Air Intakes to Minimize Introduction of Contaminants 55
Strategy 3.3 – Control Entry of Radon 58
Strategy 3.4 – Control Intrusion of Vapors from Subsurface Contaminants 62
Strategy 3.5 – Provide Effective Track-Off Systems at Entrances 68
Strategy 3.6 – Design and Build to Exclude Pests 71

Objective 4 – Control Moisture and Contaminants Related to Mechanical Systems 75
Strategy 4.1 – Control Moisture and Dirt in Air-Handling Systems 77
Strategy 4.2 – Control Moisture Associated with Piping, Plumbing Fixtures, and Ductwork 80
Strategy 4.3 – Facilitate Access to HVAC Systems for Inspection, Cleaning, and Maintenance 82
Strategy 4.4 – Control *Legionella* in Water Systems 85
Strategy 4.5 – Consider Ultraviolet Germicidal Irradiation 87

Objective 5 – Limit Contaminants from Indoor Sources 90
Strategy 5.1 – Control Indoor Contaminant Sources through Appropriate Material Selection 92
Strategy 5.2 – Employ Strategies to Limit the Impact of Emissions 97
Strategy 5.3 – Minimize IAQ Impacts Associated with Cleaning and Maintenance 101

Objective 6 – Capture and Exhaust Contaminants from Building Equipment and Activities 104
Strategy 6.1 – Properly Vent Combustion Equipment 106
Strategy 6.2 – Provide Local Capture and Exhaust for Point Sources of Contaminants 108
Strategy 6.3 – Design Exhaust Systems to Prevent Leakage of Exhaust Air into Occupied Spaces or Air Distribution Systems 111
Strategy 6.4 – Maintain Proper Pressure Relationships Between Spaces 114

Objective 6 – Capture and Exhaust Contaminants from Building Equipment and Activities 514
Strategy 6.1 – Properly Vent Combustion Equipment 514
Strategy 6.2 – Provide Local Capture and Exhaust for Point Sources of Contaminants 518
Strategy 6.3 – Design Exhaust Systems to Prevent Leakage of Exhaust Air into Occupied Spaces or Air Distribution Systems 523
Strategy 6.4 – Maintain Proper Pressure Relationships Between Spaces 529

Objective 7 – Reduce Contaminant Concentrations through Ventilation, Filtration, and Air Cleaning 536
Strategy 7.1 – Provide Appropriate Outdoor Air Quantities for Each Room or Zone 536
Strategy 7.2 – Continuously Monitor and Control Outdoor Air Delivery 542
Strategy 7.3 – Effectively Distribute Ventilation Air to the Breathing Zone 551
Strategy 7.4 – Effectively Distribute Ventilation Air to Multiple Spaces 554
Strategy 7.5 – Provide Particle Filtration and Gas-Phase Air Cleaning Consistent with Project IAQ Objectives 560
Strategy 7.6 – Provide Comfort Conditions that Enhance Occupant Satisfaction 583

Objective 8 – Apply More Advanced Ventilation Approaches 591
Strategy 8.1 – Use Dedicated Outdoor Air Systems Where Appropriate 591
Strategy 8.2 – Use Energy Recovery Ventilation Where Appropriate 595
Strategy 8.3 – Use Demand-Controlled Ventilation Where Appropriate 600
Strategy 8.4 – Use Natural or Mixed-Mode Ventilation Where Appropriate 610
Strategy 8.5 – Use the ASHRAE Standard 62.1 IAQ Procedure Where Appropriate 630

Appendix A – Environmental Monitoring (Strategy 1.2) 639

Appendix B – Understanding Vapor Barriers (Strategy 2.2) 645

Appendix C – Dehumidification in Virginia (Strategy 2.4) 656

Appendix D – Separation of Exhaust Outlets and Outdoor Air Intakes (Strategy 3.2) 660

Appendix E – Additional Information on Radon Control (Strategy 3.3) 663

Appendix F – Additional Information on Material Emissions (Strategy 5.1) 671

Appendix G – Single-Path Multiple-Zone System Design (Strategy 7.4) 686

Appendix H – Carbon Dioxide Generation Rates (Strategy 8.3) 695

Appendix M:

Federal-Provincial Advisory Committee on Environmental and Occupational Health, 1995,

Indoor Air Quality in Office Buildings: A Technical Guide, Table 1

Factors and Sources Affecting Indoor Air Quality and Comfort

Factor	Source
Temperature and humidity extremes	Improper placement of thermostats, poor humidity control, inability of the building to compensate for climate extremes, tenant-added office equipment and processes
Carbon dioxide	People, combustion of fossil fuels (e.g., gas and oil furnaces and heaters)
Carbon monoxide	Automobile exhaust (garages, loading docks, air intakes), combustion, tobacco smoke
Formaldehyde	Unsealed plywood or particleboard, urea formaldehyde foam insulation, fabrics, glues, carpets, furnishings, carbonless copy paper
Particulates	Smoke, air inlets, paper, duct insulation, water residue, carpets, HVAC filters, housekeeping
Volatile organic compounds (VOCs)	Copying and printing machines, computers, carpets, furnishings, cleaning materials, smoke, paints, adhesives, caulking, perfumes, hairsprays, solvents
Inadequate ventilation (insufficient outside air, insufficient airflow, inadequate circulation)	Energy-saving and maintenance measures, improper system design or operation, occupant tampering with HVAC system, poor office layout, system unbalanced
Microbial matter	Stagnant water in HVAC system, wet and damp materials, humidifiers, condensate drain pans, water towers

Appendix N:

Federal-Provincial Advisory Committee on Environmental and Occupational Health, 1995, Indoor Air Quality in Office Buildings: A Technical Guide, Table 2

Odours as Problem Indicators in Office Buildings

Description	Problem	Complaints
Auto exhaust, diesel fumes	Carbon monoxide	Headaches, nausea, dizziness, tiredness
Body odour	Overcrowding, low ventilation rate (high carbon dioxide levels)	Headaches, tiredness, stuffiness
Musty smell	Microbial material, wet surfaces	Allergy symptoms
Chemical smell	Formaldehyde, pesticides, other chemicals	Eye, nose, and throat irritation
Solvent smell	VOCs	Odour, allergy symptoms, dizziness, headache
Wet cement, dusty, chalky smell	Particulates, humidification system	Dry eyes, respiratory problems, nose and throat irritation, skin irritation, coughing, sneezing
Sewage gas odour	Water traps dry in floor drains in washrooms or basement	Foul smell

Appendix O:

Federal-Provincial Advisory Committee on Environmental and Occupational Health, 1995

Indoor Air Quality in Office Buildings: A Technical Guide, Table 3

Commonly Encountered VOCs and Their Sources

Chemical	Source
Acetone	Paint, coatings, finishers, paint remover, thinner, caulking
Aliphatic hydrocarbons (octane, decane, undecane hexane, isodecane, mixtures, etc.)	Paint, adhesive, gasoline, combustion sources, liquid process photocopier, carpet, linoleum, caulking compound
Aromatic hydrocarbons (toluene, xylenes, ethylbenzene, benzene)	Combustion sources, paint, adhesive, gasoline, linoleum, wall coating
Chlorinated solvents (dichloromethane or methylene chloride, trichloroethane)	Upholstery and carpet cleaner or protector, paint, paint remover, lacquers, solvents, correction fluid, dry-cleaned clothes
n-Butyl acetate	Acoustic ceiling tile, linoleum, caulking compound
Dichlorobenzene	Carpet, moth crystals, air fresheners
4-Phenylcyclohexene (4-PC)	Carpet, paint
Terpenes (limonene, α-pinene)	Deodorizers, cleaning agents, polishes, fabrics, fabric softener, cigarettes

Appendix P:

Government of Alberta, 2012, Environmental Public Health Indoor Air Quality Manual, Various Guidelines, Standards, Figures and Tables

A.1.2.5 Guidelines

A.1.2.5.1 Health Canada

Residential indoor air quality guideline – carbon monoxide (2010)	
Guidelines	***Averaging time***
28.6 mg/m^3 (25 ppm)	1 hour
11.5 mg/m^3 (10 ppm)	8 hour

Source: Health Canada (2010) Residential Indoor Air Quality Guideline Carbon Monoxide. Website: http://www.hc-sc.gc.ca/ewh-semt/pubs/air/carbon_mono/index-eng.php

These guidelines were derived based on the toxicokenetic model developed by Gosselin *et al.* (2006) and have been established to maintain COHb levels in blood below two per cent (Health Canada, 2010)

A.1.2.5.2 World Health Organization

WHO guidelines for indoor air quality: selected pollutants (2010)	
Guidelines	***Exposure time***
100 mg / m^3 (87 ppm)	For 15 minutes
35 mg/m^3 (52 ppm)	For 1 hour
10 mg/m^3 (25 ppm)	For 8 hours
7 mg/m^3 (10 ppm)	For 24 hours

Source: Carbon Monoxide, Environmental Health Criteria Series, WHO, IPCS, No. 213 (2nd edition) Summary; (http://www.who.int/pcs/ehc/summaries/ehc_213.html)

The above guidelines were derived using the Coburn-Forster-Kane equation to maintain the COHb level of two per cent for a normal adult under resting conditions for the various intervals (WHO, 2010).

A.1.2.5.3 United States Environmental Protection Agency

Unites States Environmental Protection Agency (1992)	
Percentage of COHb	***Explanation***
2.9 – 3.0 %	Ambient air exposure standards should be established to prevent the formation of 3% or less COHb to prevent myocardial ischemia

"Cardiovascular effects, as measured by decreased time to onset of angina pain and by decreased time to onset of significance ECG ST-segment depression, are judged to be the health effects of greatest concern which clearly have been associated with CO exposure at levels observed in the ambient air" (USEPA 1992)

Source: USEPA 1992, Review of the National Ambient Air Quality Standards for CO. Assessment for Scientific and Technical Information. OAQPS Staff Paper. August 1992

The following table presents steady state concentrations of indoor CO_2, which should not be exceeded indoors, for ventilation rates of 5 cfm and 10 cfm of outdoor air.The values presented in the table below were calculated using the following equation.

$$C_s - C_o = N/V_o \quad \text{eq. (1)}$$

C_s = CO_2 concentrations in space
C_o = CO_2 concentrations in outdoor air= 368 ppm + (1.5 ppm/yr * 12 yrs) = 86 ppm
N = CO_2 generation rate per person = 0.31litres/min
V_o = Outdoor air flow rate per person

As reported in the *Technical Summary Report of Inter Governmental Panel on Climate Change (IPCC)*, the average concentration of CO_2 in the ambient air in the year 2005 was 379 ppm. The reader should bear that there is an average increase of 1.5 ppm of CO_2 each year. This rate has fluctuated between 0.9 ppm/year and 2.8 ppm/year over the period 1990 to 1999 (IPCC 2001, 2007).

A.1.3.3.1.1 American Society of Heating, Refrigerating and Air Conditioning Engineers

	Outdoor air requirement (cfm/person)	Outdoor air requirement (litre/second/person) V_o	Steady state concentration of CO_2 relative to outdoor air (calculated using the equation provided above) $C_s - C_o$	Steady state CO2 + ambient bkgrd concentration of 386 ppm $C_s + C_o$
School	10	5	2,067 ppm	2,453 ppm (~ 2,500 ppm)
Offices and residences	5	2.5	1,033 ppm	1,419 ppm (~ 1,500 ppm)

Source: ASHRAE 1981. Standard 62-1-2010-Ventilation for Acceptable Indoor Air Quality. American Society for Heating Refrigerating and Air Conditioning Engineers (updated and modified).

A.1.3.3.1.2 Health Canada

Exposure guidelines residential indoor air quality	
≤ 6,300 mg/m³ (≤ 3,500 ppm)	Acceptable long-term exposure range (ALTER) for CO_2 in residential indoor air

Source: Exposure Guidelines for Residential Indoor Air Quality, A report of The Federal Provincial Advisory Committee on Environmental and Occupational Health, Health Canada 1987 (Revised and updated)

Based on the health considerations, the acceptable long-term exposure range (ALTER) for carbon dioxide in residential indoor air is less than or equal to 6,300 mg/m^3 (≤ 3,500 ppm).

- Inflammation, which is much like a sunburn on the skin
- Aggravation of asthma and increased susceptibility to respiratory illnesses like pneumonia and bronchitis

These effects are reversible, with improvement and recovery varying from a few hours to days after an elevated ozone exposure (USEPA, 2012). However, studies show that short-term exposure to ozone is also associated with increased daily mortality and permanent lung damage with repeated exposures (USEPA, 2012)

A.1.4.4 Exposure

Exposure to ozone can occur both indoors and outdoors. Inhalation and dermal contact are two routes of indoor ozone exposure, with the inhalation pathway considered to be more significant. The dynamic between outdoor and indoor ozone and personal exposure is very complex.

A.1.4.5 Guidelines

A.1.4.5.1 Health Canada - Residential

Residential indoor air quality guideline – ozone (2010)	
40 µg/m³ (20 ppb)	8 hour

Source: Health Canada (2010) Residential Indoor Air Quality Guideline Ozone. Website: http://www.hc-sc.gc.ca/ewh-semt/pubs/air/ozone/index-eng.php

A.1.4.5.2 World Health Organization

WHO air quality guidelines for ozone (2005)	
100 µg/m³	8 hour mean

Source: WHO (2005) WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide. WHO Press, World Health Organization. Geneva, Switzerland

A.1.4.6 Control Measures

There are various control measures to control, reduce or eliminate ozone from indoor air.

- Photocopiers
  - Ozone emissions from the photocopiers can be controlled or reduced by routine maintenance and cleaning. Photocopier manufacturers should include specifications on the amount of ozone produced by each model.
  - Photocopiers should be located in a well-ventilated and separate room. In some circumstances, such as extensive use and commercial use, local exhaust ventilation is recommended.
  - Some photocopiers have the option of being fitted with a "hopcalite filters," which can reduce ozone emissions.
- Electronic air cleaners and negative ion generators
  - Ensure proper installation. The use of positive coronas instead of negative coronas can significantly reduce the production of ozone from air cleaners.

A.1.5.4.1 Sensitive or vulnerable individuals

The following groups of individuals show hypersensitivity to NO_2.

- Asthmatic individuals (Calgary Health Region, 1993)
- Patients with chronic obstructive pulmonary disease (COPD)
- Children

  Compared to healthy people, children and individuals with respiratory illnesses including asthma are more susceptible to the effects of NO_2. Children can be more susceptible to colds and flu when exposed to low levels of NO_2. Bronchial reactivity is found to be increased in some asthmatic individuals when exposed to NO_2. Lung function decreased in patients with chronic obstructive pulmonary disease during long term exposure to low level NO_2. Breathing high levels of NO_2 can cause irritation of the respiratory tract and shortness of breath in humans.

A.1.5.5 Exposure

The primary route of exposure to NO_2 is through inhalation. A causal relationship has been reported between increased risk of pulmonary symptoms in children under seven years of age and living in homes with a gas stove (because of elevated NO_2). The presence of a gas stove is a significant risk factor for respiratory illnesses among those children (Godish, 2000).

In a North American study, children under the age of seven were exposed to 16 ppbv NO_2 from kerosene heaters. They were reported to have more than a two-fold higher risk of lower respiratory symptoms than children residing in homes with non-kerosene heaters (Godish, 2000).

A.1.5.6 Guidelines

A.1.5.6.1 Health Canada

Exposure guidelines for residential indoor air quality	
480 $\mu g/m^3$ (0.25 ppb)	Acceptable short-term exposure range (ASTER) for CO_2 in residential indoor air
100 $\mu g/m^3$(0.05 ppb)	Acceptable long-term exposure range (ALTER) for CO_2 in residential indoor air

Source: Exposure Guidelines for Residential Indoor Air Quality, A report of The Federal Provincial Advisory Committee on Environmental and Occupational Health, Health Canada 1987 (Revised and updated)World Health Organization

A.1.5.6.2 World Health Organization

WHO air quality guidelines for nitrogen dioxide (2005)	
200 $\mu g/m^3$	1 hour mean
40 $\mu g/m^3$	Annual mean

Source: WHO (2005) WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide. WHO Press, World Health Organization. Geneva, Switzerland

Table A.2-4 VOCs from building materials and consumer products

Building materials / consumer products	Major VOCs
Adhesives, spot cleaners, alkyd paints, paint removers, particleboard, furniture waxes	Benzene
Floor/wall coverings, fibreboard, caulking compounds, particleboard	2-Butanone
Edge sealings, molding tapes, jointing compounds, cement flagstones, linoleum floor coverings, floor lacquers, industrial cleaners, paint removers	n-Butyl alcohol
Solvent for paint, used in manufacture of phenol	Chlorobenzene
Solvent for lacquers and resins, paint and varnish removers	Cyclohexane
Plasticizer	Dibutylphthalate
Floor/wall coverings, insulation foam, chipboard, caulking compounds, jointing compounds, fibreboard, adhesives, floor lacquers, grease cleaners	Ethyl benzene
Major Sources: MDF, plywood, particleboard, ceiling panels, fibreboard, chipboard. Minor Sources: Upholstery fabrics, latex-based fabrics, fibreglass, fibreglass insulation in air ducts, urea formaldehyde foam insulation, wallpaper, caulking compounds, jointing compounds, floor and furniture varnishes, adhesives, floor lacquers, gypsum board.	Formaldehyde
Edge sealings, molding tapes, jointing compounds, cement flagstone, linoleum floor coverings, floor lacquers	Isobutyl alcohol
Paints, adhesives, chipboard, detergents, furniture polish	d-Limonene
Paint removers, aerosol paints, industrial solvents	Methylene chloride
Wallpaper, caulking compounds, floor coverings, chipboard, adhesives, cement flagstone, jointing compounds, floor varnishes, floor waxes	Nonane
Manufacturing byproduct in carpets with BR latex backing	4-Phenylcyclohexene
Insulation foam, jointing compounds, fibreboard, carpets with SBR latex backing	Styrene
Furniture polishes	α-Terpinene
Widely used in the textile industry for dry cleaning, processing, and finishing of fabrics; used in metal degreasers, spot removers, adhesives, wood cleaners, and lubricants.	Tetrachloroethylene
Solvent-based adhesives, water-based adhesives, edge sealings, molding tapes, wallpaper, jointing compounds, floor coverings, vinyl coated wallpaper, caulking compounds, paints, chipboard, vinyl floor coverings	Toluene
Solvent for paints and varnishes	Trichloroethylene
Floor/wall coverings, floor waxes, linoleum floor coverings, caulking compounds, vinyl coated wallpaper, jointing compounds, cement flagstone, floor varnishes, chipboard	Trimethylbenzene family of compounds 1,2,3 Trimethylbenzene 1,2,4 Trimethylbenzene 1,3,5 Trimethyl benzene
Adhesives, jointing compounds, wallpaper, caulking compounds, floor coverings, floor lacquers, grease cleaners, varnishes	Xylenes

Source: California Department of Health Services 1996. Reducing Occupant Exposure to Volatile Organic Compounds (VOCs) from Office Building Construction Materials: Non-binding Guidelines, Appendix B: VOCs That May Be Emitted from Building Materials and Cleaning Products. Online document: 1999, website: http://www.cal-iaq.org/VOC/VOC.

exposed to clean air. Several other exposure related studies on TVOC by USEPA revealed other health effects such as headache and general discomfort.

Molhave (2001) summarized the health effects results from several controlled human exposure experiments. The goal was to establish a dose–response relationship. Human subjects were exposed to a VOC mixture that ranged from 0.087 mg/m^3 to 25 mg/m^3. Table A.2-9 lists the various health symptoms reported in the tests.

Table A.2-9 Symptoms following VOC exposures

Symptom (health effects)	Range of thresholds showd (mg/m^3)	Number of reported cases
Perceived air quality	1.7-5	12
Odor intensity	1.0-1.7	12
Irritation of eyes or nose	1.7-8.0	12
Additional ventilation needed	1.7-3.0	5
Feeling of cough	1.7-25	3
Irritation of throat	5-25	12
General well being	8-10	4
Feeling of skin humidity	10-25	3
Headache	≥ 20	5
Concentration difficulties	12=20	5
Feeling of sleepiness	≥ 25	3

Source: Molhave (2001), Sensory irritation by VOCs: 12 exposure experiments, chapter 25, Indoor Air Quality Handbook, McGraw Hill publications (2001).

A.2.2.4 Guidelines

A.2.2.4.1 TVOC concentration and comfort range in residential environment

Based on the dose–response studies conducted by Molhave, the following table summarizes the relationship between TVOC exposure and health effects (Table A.2-10). The TVOC dose-relationship in the table provides a useful tool for indoor air quality investigators, but should be used judiciously with an understanding of site-specific VOC sources and contaminants of concern.

Table A.2-10 Molhave's TVOC dose–response model relationship

TVOC concentration (mg/m^3)	Response	Exposure range
< 0.20	No effects	Comfort range
0.20 – 3.0	Irritation / discomfort possible	Multifactorial exposure range
3.0 – 25.0	Irritation and discomfort; headache possible	Discomfort range
> 25.0	Neurotoxic effects	Toxic Range

With reference to the above table, Dr. Molhave states that for normal and average people, the threshold for headache and other weak neurotoxic effects by exposure of less than a few hours duration are expected to be between 3 mg/m^3 and 25 mg/m^3. However, more sensitive individuals may experience these health effects at concentrations lower than those specified above.

A.2.2.4.2 TVOC range in office buildings

- **Health Canada**

At present there are no Canadian standards for TVOC. However, Health Canada has presented the following quantitative TVOCs guidelines for office buildings (Table A.2-11).

Table A.2-11 Health Canada recommended TVOC levels in office buildings

Jurisdiction	TVOC criteria	
Tentative North American criteria	Target level for TVOC	1 mg/m^3
	Action level for TVOC	5 mg/m^3
European Community	Target (see the section below for more information)	0.3 mg/m^3 with no one VOC exceeding 10% of the TVOC concentration
Molhave criteria	See Table A.2-10	

Source: Indoor Air Quality in Office Buildings: A Technical Guide, Health Canada, Minister of Supply and Services Canada, 1995

Health Canada states that sensitive individuals can be severely affected by a variety of VOCs at very low concentrations. They can react to organic compounds that are released by building materials, carpets, and various consumer products including cosmetics, soaps, perfumes, tobacco, plastics and dyes. These reactions can occur after exposure to a single sensitizing dose or a sequence of doses. After a sensitizing dose, a much lower dose can provoke health symptoms. Because of the limited knowledge of toxicological and sensory effects of VOC mixtures, reduction of overall exposure to TVOC is highly desirable.

- **European Community target guidelines**

The European Collaborative Action (ECA) report no. 11, *Guidelines for Ventilation Requirements in Buildings* (CEC, 1992) lists TVOC concentration ranges as measured with a flame ionization detector calibrated to toluene. These recommendations are based on Molhave's toxicological studies on mucous membrane irritation (Molhave, 1990).

  - Comfort range: < 200 ug/m^3 (< 0.2 mg/m^3)
  - Multifactorial exposure range: 200 to 3,000 ug/m^3 (0.2 to 3 mg/m^3)
  - Discomfort range: 3,000 to 25,000 ug/m^3 (3 to 25 mg/m^3)
  - Toxic range: > 25,000 ug/m^3 (> 25 mg/m^3)

A second criteria is based on the research of Seifert (1990) who has established TVOC guidelines based on the ten most prevalent compounds in each of seven chemical classes. The concentrations in each of these classes should be below the maximums listed below.

  - Alkanes: 100 ug/m^3 (0.1 mg/m^3)
  - Aromatic hydrocarbons: 50 ug/m^3 (0.05 mg/m^3)
  - Terpenes: 30 ug/m^3 (0.03 mg/m^3)
  - Halocarbons: 30 ug/m^3 (0.03 mg/m^3)

Table A.2-14 Major sources of benzene exposure and risk

Activity	Intake (µg/day)	Population at risk	Total exposure risk
Smoking	1,800	53	50
Unknown personal	150	240	20
Ambient	120	240	20
Passive smoking	50	190	5
Occupational	10,000	0.25	1
Filling petrol (gas tank)	10	100	<1

Source: Wallace (2001). "Assessing Human Exporusre to Voltaltie Organic Compounds," Chapter 33. Indoor Air Quality Handbook, edited by Spengler et. Al. (2001) McGraw Hill Publications, 2001.

The total exposure risk estimate presented in Table A.2-14 was determined by taking into consideration various benzene exposure scenarios from different sources, such as ambient exposure, sitting in a vehicle, gas-tank filling, active smoking, passive smoking, attached garages, household products and materials, exposure from industries and wood smoke. After comparing all the sources, it was determined that smoking alone constituted approximately half of the U.S. population's total benzene exposure and the remaining half was distributed between personal activities (approximately 30 per cent) and the outdoor sources (approximately 20 per cent). The unidentified personal activity factors may include indoor exposure from the variety of unspecified products and materials in a home that are known to contain and release benzene into indoor air.

A.2.3.7 Guidelines

- **Health Canada**

Health Canada toxicological reference values (TRVS)	
3.3E-3 (mg/m3)-1	Inhalation unit risk from TC05a

a - Inhalation unit risk derived as: URInh = 0.05/TC05; TC05 from Health Canada (1996);

Source: Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs). (2004) Health Canada Website: http://www.hc-sc.gc.ca/ewh-semt/alt_formats/hecs-sesc/pdf/pubs/contamsite/part-partie_ii/part-partie_ii-eng.pdf

- **World Health Organization**

WHO guidelines for indoor air quality: selected pollutants (2010)	
1.7 ug/m^3	1 in 100,000 risk

WHO (2010). WHO guidelines for indoor air quality: selected pollutants. World Health Organization. Website:
http://www.euro.who.int/data/assets/pdf_file/0009/128169/e94535.pdf

A.2.4.2 Exposure

Exposure to toluene may take place from many sources, including drinking water, food, air and consumer products, breathing the chemical in the workplace or deliberate glue-sniffing or solvent abuse. Automobile exhaust also puts toluene into the air. People who work with gasoline, kerosene, heating oil, paints and lacquers are at the greatest risk of exposure (ATSDR, 2000).

Because toluene is a common solvent and is found in many consumer products, you can be exposed to toluene at home, at work, indoors and outdoors. Using gasoline, nail polish, cosmetics, rubber cement, paints, paintbrush cleaners, stain removers, fabric dyes, inks, adhesives, carburetor cleaners and lacquer thinners provides an opportunity for exposure to occur. Smokers are exposed to small amounts of toluene in cigarette smoke and add it to the air increasing the exposure potential for non-smokers (ATSDR, 2000).

The highest concentrations of toluene usually occur in indoor air as a result of using common household products, such as paints, paint thinners, adhesives, synthetic fragrances and nail polish, and cigarette smoke. The deliberate inhalation of solvent-based products, such as glue and paint, by solvent abusers may result in high levels of exposure to toluene as well as to other chemicals (USEPA, 2007).

The toluene level in the air outside your home is usually less than 1 ppm in cities and suburbs that are not close to industry and is expected to the same in the indoor environment (ATSDR, 2000). Unless you smoke cigarettes or work with toluene-containing products, you are probably exposed to only minute amounts of toluene each day. Smoker who smoke a pack of cigarettes per day add 1,000 μg to their exposure. People who work in places where toluene-containing products are used with an air concentration of 50 ppm increase their exposure by 1,000 mg each day of work (ATSDR, 2000).

A.2.4.3 Guidelines

- **Health Canada**

  The recommended short- and long-term maximum exposure limits for toluene are presented in the table below. Exposure to indoor air concentrations above these limits may result in potential health effects.

Residential indoor air quality guideline – toluene (2011)	
Guidelines	***Averaging time***
15 mg/m^3 (4 ppm)	Short-term (8 hour)
2.3 mg/m^3 (0.6 ppm)	Long-term (24 hour)

Source: Health Canada. (2011) "Residential Indoor Air Quality Guideline – Toluene". Website: http://www.hc-sc.gc.ca/ewh-semt/pubs/air/toluene/index-eng.php

The short-term exposure limit was derived based on a no observed adverse effect level (NOAEL) of 151 mg/m^3 from the study by Andersen et al. (1983) of healthy adult volunteers exposed for seven hours to toluene, and screened for neurologically-related symptoms, such as headaches, dizziness and intoxication. Applied to this NOAEL was an uncertainty factor of 10 (3.16 for pharmacokinetics and 3.16 for pharmacodynamics) to account for the potential differences in sensitivity among individuals.

A long-term exposure limit was derived from an NOAEL of 98 mg/m³ from the studies by Seeber et al. (2004; 2005) of printing shop workers, exposed for more than 20 years to toluene, and screened for neurobehavioural endpoints, such as attention span, psychomotor function and memory. This value was then adjusted to account for the difference in the duration of exposure for people in a workplace compared to people in a residence from eight hours/day, five days/week to 24 hours per day, seven days a week. Applied to this value was an uncertainty factor of 10 (3.16 for pharmacokinetics and 3.16 for pharmacodynamics) to account for the potential differences in sensitivity among individuals.

- **World Health Organization**

WHO guidelines for indoor air quality: selected pollutants (2010)	
Guidelines	*Exposure time*
0.26 mg / m³ (87 ppm)	1 week

Source: WHO (2000). Air Quality Guidelines for Europe, 2nd Edition. World Health Organization website: http://www.euro.who.int/__data/assets/pdf_file/0005/74732/E71922.pdf

This value is established from the LOAEL for effects on the central nervous system from occupational studies (332 mg/m³ or 88 ppm) and adjusting for continuous exposure (dividing by a factor of 4.2) and dividing by an uncertainty factor of 300 (10 for inter-individual variation, 10 for use of a LOAEL rather than a NOAEL, and an additional factor of three given the potential effects on the developing central nervous system). This guideline value should be applied as a weekly average. This guideline value should also be protective for reproductive effects (spontaneous abortions).

A.2.4.4 Control measures

Reduce or eliminate exposure to benzene through the following source control methodologies:

- Eliminate smoking within the home.
- Provide maximum ventilation when using of paints and varnishes.
- Discard leftover paint supplies and special fuels rather than store them or or store them in exhaust cabinets.
- Move away from the filling nozzle while refueling vehicles at gas stations.
- Use timers to ventilate periodically exhaust from attached garages or build detached garage.
- Properly maintain gas-fired furnaces and ensure they meet building code requirements.
- Minimize or curtail indoor wood-burning.
- Build new structures away from busy roadways, gas stations and other industrial sources.
- Ensure the best available pollution control equipment is installed on industrial sources.

Table A.2-17 Formaldehyde emissions from different products

Product	Range of emissions rates (ug/m^3 per day)
Medium-density fibreboard	17,600 – 55,000
Hardwood plywood paneling	1,500 – 34,000.
Particle board	2,000 – 25,000.
UFFI	1,200 – 19,200.
Softwood plywood	240 – 720.
Paper products	260 – 280.
Fibreglass products	400 – 470.
Clothing	35 – 570.

Source: Pickerell et. al., 1983, Mathews et. al., 1985, Grot et. al., 1985, In Samet et. al., 2001, cited in Spengler et. al. (2001), Indoor Air Quality Handbook, McGraw Hill publications

Historically, UFFI was used to insulate houses in North America; however UFFI use was banned in the early 1980s. Before UFFI being banned, 80,000 residences in Canada were insulated with it. As a result of the ban, current levels of HCHO in newly constructed homes are significantly lower than historical concentrations. Concentrations of HCHO in residential building in the United States and Canada do not exceed 0.10 ppmv with an average concentration of less than 0.05 ppmv. HCHO levels in office buildings rarely exceeded 0.05 ppmv. Presently, levels of HCHO in mobile homes range from 0.05 ppmv to 0.15 ppmv. However, the rate can be > 0.20 ppmv because of the pervasive presence of pressed wood products in a relatively small space (Godish, 2000). There are limited studies available on HCHO levels in new houses constructed after the 1990s (Godish, 2000).

Indoor exposure to HCHO depends on the following factors (Godish, 1989, 2000):

- Potency of the HCHO emitting products and their use
- Surface area (m^2) of sources relative to the volume (m^3) of the interior space
- Environmental factors, such as temperature and relative humidity
- Age of the source
- Ventilation

Smokers can be exposed to significant amounts of HCHO from tobacco smoke. Please refer to *Appendix C Environmental tobacco smoke*for more information on the hazards associated with cigarette smoke in the indoor environment.

A.2.5.6 Guidelines

- **Health Canada – residential**

Residential indoor air quality guideline – formaldehyde (2006)	
123 $\mu g/m^3$ (100 ppb)	1 hour
50 $\mu g/m^3$ (40 ppb)	8 hours

Source: Health Canada. (2006) "Residential Indoor Air Quality Guideline – Formaldehyde". Website: http://www.hc-sc.gc.ca/ewh-semt/pubs/air/toluene/index-eng.php

A.2.6.3 Exposure

Human exposure to individual PAHs and PAH mixtures occur by (Fiala *et. al.*, 2001):

- Direct inhalation of indoor air contaminated with Environmental Tobacco Smoke, wood smoke and contaminated air from the outdoors
- Dermal contact with soot, tars and polluted soils (IARC, 1983)
- Dietary intake of fried, broiled, sautéed and barbecued foods and contaminated drinking water

In the indoor environment, inhalation can be a significant exposure route. PAHs in indoor air can originate from residential heating (wood burning) and environmental tobacco smoke at average concentrations from 1 ng/m^3 to 100 ng/m^3, with a maximum of 2,300 ng/m^3 (WHO, 1998). Contaminated indoor air is an important source of PAH exposure for humans. In addition to other chemicals, PAHs constitute one of the major carcinogenic (not all PAHs are carcinogenic) agents in environmental tobacco smoke. The reader should refer to *Appendix C Environmental tobacco smoke* for more information on environmental tobacco smoke.

In general, however, the available data suggests the oral route is the major route of exposure to PAHs (ATSDR, 1995). The intake of individual PAHs from food has been estimated at 0.10 ng/m^3 to 10 ng/m^3 per person (WHO, 1998).

PAHs are also a common outdoor pollutant. Please refer to *Appendix G – Outdoor Air Factor* for more information on PAHs and outdoor air quality.

A.2.6.4 Exposure guidelines and risk estimates for PAHs in indoor air

- **World Health Organization**

  Because some of the PAHs are proven human carcinogens, no safe level can be recommended for exposure (WHO, 1998). In addition, PAHs in air are attached to particles, which may also play a role in their carcinogenicity (WHO, 2000). Although food is thought to be the major source of human exposure to PAHs, part of this contamination may arise from air pollution with PAHs. The levels of PAHs in air should,herefore be kept as low as possible (WHO, 2000).

  "The potency of B[a]P in humans exposed by inhalation has been assessed on the basis of extrapolations from the results for rodents, sometimes exposed other than by respiration. Since the sensitivity to PAH is likely to differ with the route of exposure, assessments made on the basis of exposure by inhalation are preferable" (cited in WHO 1998, Environmental Health Criteria Series, EHC 202).

Chemical	Average ambient air concentration (ng/m^3)	Health end point	Unit risk $(ng/m^3)^{-1}$	IARC classification
PAH- (Benzo(a)Pyrene)	<1 - 10	Lung cancer in exposed humans	8.7×10^{-5}	1

Source: WHO (2000). "Air Quality Guidelines for Europe, 2nd Edition". World Health Organization website: http://www.euro.who.int/__data/assets/pdf_file/0005/74732/E71922.pdf

- **United States Environmental Protection Agency (USEPA)**

  A number of risk estimates have been derived for PAHs, based primarily on studies in which B[a]P was used as the index compound. The USEPA(1984d) proposed an upper-bound lifetime cancer risk of 62 per 100,000 exposed people per microgram of benzene-soluble coke-oven emission per cubic metre of ambient air. Assuming a 0.71% content of benzo[a]pyrene in these emissions, it was estimated that nine out of 100,000 ($\sim 10^{-4}$) people exposed to 1 ng/m^3 B[a]P over a lifetime would be at risk of developing cancer (cited in WHO 1998)

- **Health Canada**

  Health Canada has provided health based tolerable daily intake/concentrations and Tumourigenic Doses/Concentrations for PAHs. Based on the availability of data, $TC_{0.5}$ for PAHs was derived.

Health Canada toxicological reference values (TRVS)	
3.1E-2 $(mg/m^3)^{-1}$	Inhalation unit risk from TC_{05}[a]

a - Inhalation unit risk derived as: URInh = 0.05/TC05; TC05 from Health Canada (1996)

Source: Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs). (2004). Health Canada Website: http://www.hc-sc.gc.ca/ewh-semt/alt_formats/hecs-sesc/pdf/pubs/contamsite/part-partie_ii/part-partie_ii-eng.pdf

Carcinogenic potencies of other PAHs relative to B(a)P were estimated on the basis of multistage modeling of tumor incidence (epidermoid carcinomas) in Osborne-Mendel Rats. PAHs were implanted into the left lung of those rats (Deutsch-Wenzel *et. al.*, 1983) and the potencies for each PAH relative to that of B(a)P were estimated. On this basis, relative carcinogenic potency factors are:

- Benzo(a)pyrene – 1
- Benzo(b)fluoranthene – 0.06
- Benzo(j)fluoranthene – 0.05
- Benzo(k)fluoranthene – 0.04
- Indenol (1,2,3,-cd)pyrene – 0.12

By multiplying TC_{05} for benzo(a)pyrene (1.6 mg/m^3, derived from inhalation bioassay), the following carcinogenic potencies were derived for other PAHs.

Chemicals	Carcinogenic potency (mg/m^3)
Benzo(b)fluoranthene	0.096
Benzo(j)fluoranthene	0.08
Benzo(k)fluoranthene	0.064
Indenol (1,2,3,-cd)pyrene	0.19

Source: Canadian Environmental Protection Act, Priority Substances List, Supporting Documentation: Health-Based Tolerable Daily Intakes/Concentrations and Tumourigenic Doses/Concentrations for Prior Substances

A.2.7.4 Guidelines

- **Health Canada**

  Health Canada has provided health-based tolerable concentrations for chlorinated hydrocarbons. Based on the availability of data, tolerable concentrations (TC) for chlorinated hydrocarbons was derived.

Tolerable concentrations (TC) for chlorinated hydrocarbons		
Chemical	***TC***[1]	***Explanation***
Tetrachloroethylene	0.36 mg /m^3	Based upon non-carcinogenic effects

[1]: TC: Tolerable concentrations (often expressed in mg/ m^3) are generally airborne concentrations to which it is believed that a person can be exposed continuously over a lifetime without deleterious effect. For a detailed explanation of derivation of TC values, the reader should refer to Health Canada

Source: Federal Contaminated Site Risk Assessment In Canada: Part II: Health Canada Toxicological Reference Values (TRVs). (2004). Health Canada website: http://www.hc-sc.gc.ca/ewh-semt/pubs/contamsite/part-partie_ii/index-eng.php

A.2.7.5 Control measures

Measures to control or limit exposures to PERC can include the following;

- Know what you are buying.
- Learn about cleaning processes for your garments and know what options are available.
- Bring your clothes to professional cleaners who carefully follow safety requirements and properly maintain cleaning equipment.
- Target cleaners that offer the wet-cleaning process as an option.

To control or limit exposure to TCE consider the following:

- Choose products that do not contain TCE or are low-TCE.
- Remove household sources of TCE to the outdoors.
- Maintain adequate ventilation.

observations in the swimming pool exposure scenario is uncertain. However, it should be noted that USEPA has classified chloroform as a probable human carcinogen.

Limited information is available on adverse health effects in people in occupational environments following chronic inhalation of chloroform. In a study by Bomski *et. al.* (1967), 17 cases of hepatomegaly were reported in a group of 68 chloroform-exposed workers. The chloroform concentrations ranged from 2 to 205 ppm and the exposure duration was one to four years. It was also reported that those workers were highly susceptible to viral hepatitis with a 10-fold increased risk of contracting viral hepatitis when compared with the general population. The author of this study reported chloroform-induced liver toxicity as a predisposing factor for viral hepatitis (cited in California EPA, 2001). The reader should refer to ATSDR's chloroform toxicological profile and the IRIS chloroform summary for additional information on the chronic toxicity of chloroform in humans and animals.

A.2.8.5 Exposure

There are exposures to VHHs within the swimming pool environment. They are mainly in the form of inhalation of the disinfection-byproduct contaminated air that have resulted from either the treatment of water for potability as well as the treatment of the water in the pool basin as well.

Studies show that inhalation of contaminated air from showering and training, leisure or work activities, such as. Lifeguarding, within the pool enclosure can provide exposures or increased exposures to certain DBPs (Richardson, 2005; Levesque *et. al.*, 2002; Levesque *et. al.* 2000).

A.2.8.6 Guidelines

- **Agency for Toxic Substances and Disease Registry**

Minimum risk level[1] for chloroform (inhalation exposure)	
0.1 ppm	Acute duration inhalation exposure based on a NOAEL of 3 ppm for hepatic effects in mice (Larson *et. al.*, 1994c)
0.02 ppm	Chronic duration inhalation exposure based on a LOAEL of 2 ppm for hepatic effects in workers exposed to concentrations of chloroform ranging from 2 to 205 ppm for 1-4 years (Bomski *et. al.*, 1967)

1. Minimal Risk Level is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse noncancer health effects over a specified duration for a given route of exposure. MRLs are derived for acute (1-14 days), intermediate (15-364 days) and chronic (365 days and longer) duration and for the oral and inhalation routes of exposure.

Source: Toxicological Profile for Chloroform, (1997) , Agency for Toxic Substances and Disease Registry ATSDR, website http://www.atsdr.cdc.gov/toxprofiles/tp.asp?id=53&tid=16

- **American Society for Heating, Refrigeration and Air Conditioning Engineers (ASHRAE)**

Recommended outdoor air requirements for ventilation in swimming pools	
0.48 cfm/ft^2 or 2.4 $L/s.m^2$	(ASHRAE 62.1-2010)[1]

Source: According to ASHRAE (62.1-2010), higher values may be required for humidity control

- **Agency for Toxic Substances and Disease Registry (1999)**

Agency for roxic substances and disease registry (ATSDR 1999)	
0.0002 mg/m^3	Minimal Risk Level (MRL) for chronic duration inhalation exposure (365 days or more) to metallic mercury vapour. In a group of 26 mercury-exposed workers from three industries exposed to low levels of mercury for an average of 15.3 years (Range, 1-41 years) (Fawer *et. al.*, 1983)

Source: Toxicological profile for mercury, Agency for Toxic Substances and Disease Registry (1999)

A.2.9.7 Control measures

Most pesticide use of mercury was banned in 1976. In 1990, USEPA announced that use of mercury would be eliminated from interior latex paints. Paints that contain mercury carry a warning label stating the paint is for outdoor use only. In 1998, mercury based antimicrobial pesticides and mercury-based exterior paints were phased out in Canada.

Although, the use of mercury in consumer products is severely restricted, the presence of mercury in the indoor and outdoor environments can have severe health consequences. Simple control measures can be put in place indoors to eliminate or reduce mercury exposure.

- Evaluate any existing stock of paints and properly dispose of those paints that contain mercury (USEPA, 2002)
- Mercury is used in the manufacture of various lamps and lighting fixtures, wiring devices, halide and high-pressure sodium lamps, and switches. Mercury releases are associated with the manufacture, breakage and disposal of mercury lamps and light switches. Limit and reduce the use of mercury-vapour lamps and other electrical products containing mercury, or alternatively ensure proper handling and disposal, particularly avoiding breakage indoors. Redesigning the low-dose mercury lamp will help in reducing leachable mercury.
- Follow the recommendations of a flourescent lamp stewardship program, released by Alberta Environment in June 2000. The following recommendations for mercury disposal and for recycling of mercury wastes from household hazardous products were provided. In Alberta, used fluorescent lamps intended for disposal are currently not classified as hazardous waste. However, recycling options should be considered before disposing at a landfill. Where recycling options are not available for large quantities of mercury, it has been suggested that fluorescent lamps be packaged with absorbent materials such as calcium poly-sulfide or commercially available powdered sulfur, If sulfur-based absorbent is used, it should be re-packed in a secondary container containing alkaline coating surrounding the core waste package.
- Other mercury containing wastes and materials, such as broken and obsolete instrumentation like thermometers and thermostats, should be packaged with a poly-sulfide/alkaline coating.. After mercury-containing wastes and materials are pre-treated with absorbent materials, the waste materials can be disposed at any sanitary landfill after obtaining permission from the operator.
- Carefully handle mercury-containing devices to avoid breakage and spillage
- Metallic mercury evaporates slowly, so it should be stored in an airtight, closed container (ATSDR, 1999).

F.1.1 Exposure

The primary route of indoor exposure to particulate matter is inhalation (Godish 2000, CEPA 2000). However, dermal contact and ingestion can be possible routes of exposure. A complex relationship exists between personal exposure, ambient and indoor particulate matter. The reader should refer to the *Appendix G Outdoor air factors* for a detailed discussion on correlations between personal exposure, ambient and indoor particulate matter.

F.1.2 Guidelines for $PM_{2.5}$ in indoor air

The current indoor Canadian $PM_{2.5}$ guidance (Health Canada 1995) is being revised and will be rescinded. In August, 2011, the Government of Canada advised the public that under the *Canadian Environmental Protection Act, 1999*, the Minister of Canada was revising the 1987 *Exposure Guidelines for Residential Indoor Air Quality* (Government of Canada 2011). The new guidance would consider and incorporate the most up-to-date science. The indoor $PM_{2.5}$ concentration is influenced by the highly variable ambient concentration; it is not practical to set a numerical limit. As such, there will be no new numerical exposure limit in the making. Rather, the proposed guidance will aim at reducing the $PM_{2.5}$ indoor/outdoor concentration ratio to below 1 using four reduction strategies:

- Cessation of smoking
- Use of a stove top fan while cooking
- Installation of high quality furnace filters or use of portable air cleaners
- Adequate ventilation

F.1.3 Control measures

Several measures can be carried out to control indoor particulate levels. They include:

- Replace filters on furnaces, air conditioners and air cleaners as specified by the manufacturer.
- Do regular house-cleaning.
- Avoid installaing wall-to-wall carpets.
- Have a trained professional annually inspect, clean and tune up of the chimneys and flues.
- Have properly fitting and functioning doors on all wood stoves.
- Vent all furnace combustion gases outside.
- Cease tobacco smoking indoors.
- Reduce or eliminate other indoor sources of particulates including wood- or coal-burning stoves, gas log fireplaces and natural gas stoves if these stoves are not exhaust ventilated and (USEPA 2001)
- Avoid use of pressurized consumer products that aerosolize contents.

B.3.8 Guidelines

Indoor air quality guidelines for asbestos are generally specified as "clearance" measurements that are required before re-occupying a building that was mitigated because of asbestos contamination or asbestos-containing materials. The clearance criterion is 0.01 f/cm^3 for NIOSH Method 7400 (*NIOSH Manual of Analytical Methods 1994*, Government of Alberta 2011, Spengler et al. 2001).

Specific indoor air guidelines for asbestos are not recommended because IARC and USEPA regard asbestos as a proven human carcinogen. In other words, there is no safe level of exposure to a carcinogen. Exposure to asbestos should be avoided or be kept as low as possible. However, several risk estimates have been developed by the regulatory agencies, such as WHO 2000, Government of Alberta, 2011, with respect to asbestos exposure.

Several researchers have derived lifetime exposure estimates with respect to asbestos and public health protection. The "best estimate" is that lifetime exposure to 1000 F/m^3 (0.0005 F^*/cm^3 or 500 F^*/m^3, F^* = fibres counted with an optical microscope) in a population where 30 per cent are smokers and the excess risk because of lung cancer would be in the range of 10^{-6} to 10^{-5}. The corresponding mesothelioma risk for this population would range from 10^{-5} to 10^{-4}. These values have been proposed to provide adequate health protection to the public. However, the validity of those risk estimates is critical to judge (WHO 2000). More recently WHO's (WHO 2006) is committed to work with countries by establishing the following strategic directions to eliminate asbestos-related diseases:

- Stop the use of all types of asbestos.
- Replace asbestos with safer substitutes and develop economic and technological mechanisms to stimulate its replacement.
- Establish protocols to prevent asbestos exposure during abatement.
- Improve early diagnosis, treatment, social and medical rehabilitation of asbestos-related diseases and establish registries of people with past and current exposure to asbestos.

B.3.8.1 Agency for Toxic Substances and Disease Registry 2001

Asbestos is a proven human carcinogen, minimal risk levels (MRLs) are not available. However, several risk estimates are available and were reported in the *Toxicological Profile for Asbestos* (ATSDR 2001). Table B.3-3 presents lung risk estimate data for male and female smokers and nonsmokers with respect to lifetime exposure to 0.0001 f/cm^3. It is also important to note that the fibres concentrations reported here are for PCM (Phase Contrast Microscopy) and not TEM (Total Electron Microscopy).

Table B.3-3 Risk assessment for asbestos-associated lung cancer

	Smokers			Nonsmokers		
Parameters	*Male*[a]	*Female*[a]	*Average*[b]	*Male*[a]	*Female*[a]	*Average*[b]
Lung cancer risk from lifetime exposure to 0.0001 f/cm^3	2.4 x 10^{-5}	1.5 x 10^{-5}	2.0 x 10^{-5}	0.2 x 10^{-5}	0.2 x 10^{-5}	0.2 x 10^{-5}
Concentration (f/cm^3) corresponding to lifetime excess risk level of 10^{-4}			0.0005			0.005
Cumulative dose (f-yr/ cm^3) for a 70-year exposure corresponding to 10^{-4} risk level			0.035			0.35

[B]Average of males and females

Note: The concentration corresponding to lifetime excess risk level and the cumulative dose for a 70 year exposure risk level were calculated on the basis of 10-4 risk level. However, 10^{-5} (1 in 100,000) or 10^{-6} (1 in 1 million) risk level is usually considered acceptable in Canada. Adjustment in the calculations should be made for the purpose of comparison between 10^{-4}, 10^{-5} and 10^{-6} levels of risk.

[A]*Source: ATSDR, 2001 (Original Source: EPA (1986a)*

Table 3-4 Integrated risk information system (USEPA, 2000)

Inhalation unit risk estimate and air concentrations at specified risk levels, IRIS 2001	
Inhalation unit risk[1]	*2.3 x 10^{-1} per (PCMf/cm^3)*[1]
Risk level	Concentration
10^{-4} (1 in 10,000)	4 x 10^{-4} f/mL
10^{-5} (1 in 100,000)	4 x 10^{-5} f/mL
10^{-6} (1 in 1,000,000)	4 x 10^{-6} f/mL

[1]Unit Risk is the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to 1 pcm fibre/cm3. For asbestos, the unit risk value is calculated for the additive combined risk of lung cancer and mesothelioma and is calculated as a composite value for males and females. The unit risk value is based on risks calculated using general population cancer rates and mortality patterns without considering smoking habits of populations in USA. The unit risk is based on fibre counts made by phase contrast microscopy (PCM) and should not be applied directly to measurements made by other analytical techniques. The unit risk uses PCM fibres because PCM is used in the occupational environment.

B.3.8.2 Health Canada

Health Canada states that the asbestos content of a product does not indicate its health risk. Health risks exist only when fibres are in the air that people breathe.

Health Canada has encouraged provincial occupational health authorities to adopt stringent workplace exposure limits for asbestos. The sale of pure asbestos and certain high risk consumer products that are composed of or contain asbestos fibres is strictly regulated by Asbestos Products Regulations under the Canada Consumer Product Safety Act 2010. In addition, the emissions of asbestos into the environment from mining and milling operations are subject to the Canadian Environmental Protection Act 1999 (Health Canada 2008).

Health Canada recognizes the importance of reducing the exposure to asbestos fibres. During home renovations and maintenance activities, precautions should be taken to minimize the inhalation of asbestos. In addition, materials and products containing asbestos should be examined periodically for signs of deterioration. Before, removing or disturbing any asbestos-suspect materials, information and advice should be sought from government agencies and/or consultants.

(Hedge et al. 1993, Sainmi 1990, Spengler et al. 2001). World Health Organization (2000d) have reported that MMMFs >3 μm can cause transient irritation and inflammation of the skin, eyes and upper respiratory airways.

MMMFs are also associated with "office eye syndrome," collective dermatitis and upper respiratory tract irritation (Valarino 2001, Spengler et al. 2001). These symptoms have been observed in new employees in an office setting (Vallarino 2001).

- **Chronic and carcinogenic effects**

  Recent studies have provided epidemiological data on MMMFs (Vallarino 2001, Spengler et al. 2001). Statistically, higher risks of lung cancer and other respiratory cancers have been observed in mineral fibre manufacturing facility workers (Enterliine 1987, Simonato et al. 1987, Spengler et al. 2001). However, several investigators have attributed these lung cancers to other cofactors, such as smoking, but not to MMMFs (Chiazze et al. 1995). IARC evaluated the evidence in 2002 and only kept the more biopersistent materials, such as refractory ceramic fibre (RCF) as possible human carcinogens (Group 2B). Other MMMFs including insulation glass wool, rock (stone) wool, and slag wool are now no longer classified as to their carcinogenicity to humans (Group 3). The 2002 IARC evaluation is supported by more recent studies. Lipworth and co-workers in 2009 (Lipworth et al. 2009) conducted a systematic review and meta-analysis and argued against a carcinogenic effect of rock wool or glass wool. NTP (2010) has similarly concluded that there is inadequate evidence to suggest glass wool fibres are carcinogenic.

B.4.6 Guidelines and standards

Occupational guidelines have been established for non-carcinogenic fibres, and exposure limits are recommended for potential carcinogenic fibres. For regulatory purpose, a particle is considered as a fibre when the length (L) is >5 μm and the diameter (D) <3 μm, and a L:D ratio >3:1. Fibres correspond to the respirable fraction of particular matters that is able to enter the alveolar region of humans.

- **Fibres with no indication for carcinogenicity**

  More commonly used vitreous fibre wools including insulating glass wool, such as fibreglass, rock (stone) wool and slag wool are now considered as non-carcinogenic to humans (Group 3) (IARC 2001). Based on reviews and published articles, the Scientific Committee on Occupational Exposure Limits for Man-made Mineral Fibres (European Commission 2012) has recommended the following occupational guidelines for fibres with no indication for carcinogenicity and not specified elsewhere.

Table B.4-1 Fibres with no indication of carcinogenicity

Recommended guidelines	Recommended concentration
8 hour TWA	1 fibre/ml
OEL	1 fibre/ml
STEL (15 minutes)	---

Source: European Commission 2012.

The Government of Alberta Occupational Health and Safety Code (Government of Alberta 2009) has established guidelines for fibres that have no indication for carcinogenicity.

Table B.4-2 Government of Alberta guidelines for fibres with no indication of carcinogenicity

Types of synthetic vitreous fibres	8-hour OELs
Glass fibres, continous filament	1 fibre/cc
Glass fibres, continous filament, total particulate	5 mg/m^3
Glass fibres, special purpose	1 fibre/cc
Rock wool fibres	1 fibre/cc
Slag wool fibres	1 fibre/cc

Source: Government of Alberta Occupational Health and Safety Code

- **Fibres classified as possible human carcinogens**

While most MMMF are non-carcinogenic, IARC (2001) has classified refractory ceramic fibres (RCF) and some special purpose glass wools that are not used as insulating materials as possible human carcinogens (Group 2B). Lung inflammation contributes to cancer development (de Visser et al, 2005) and that inflammation occurrence is determined by doses (particles and fibres) (Schins 2002),[iii] it is therefore assumed that fibre toxicity and carcinogenicity of RCF has a threshold. The World Health Organization (2000d)[iv] has suggested unit risks and excess lifetime cancer risk for the biopersistent refractory ceramic fibres based on dose/concentration

Table B.4-3. Lifetime cancer risk for biopersistent refractory ceramic fibres based on dose concentration

Number of fibres/1,000 cm^3	Excess lifetime cancer risk
100	1 in10,000
10	1 in 100,000
1	1 in 1,000,000

Source:: World Health Organization (2000d), Man-made Vitreous Fibres, Air Quality Guidelines for Europe

Because refractory ceramic fibres are suspected human carcinogen, the American Conference of Governmental Industrial Hygienists (ACGIH 2000) has recommended a lower threshold limit value-time-weighted average of 0.2 fibres/cc, while all other fibres have a higher TLV-TWA of 1 fibre/cc.

Table B.4-4 ACGIH recommended TLV-TWA

Fibres	ACGIH TLV-TWA
Refractor ceramic fibres (RCF)	0.2 fibres/cc

Source: American Conference of Governmental Industrial Hygienists (ACGIH). 2002. Documentation of TLV for synthetic vitreous fibres. In: Chemical Substances TLVs and BEIs. 7th edition. Cincinnati. Ohio.

The Alberta Government has established OEL for RCF. The limit considers the RCF carcinogenicity classification of A2 (a suspected human carcinogen) based on the ACGIH classification (Government of Alberta 2009).

Table B.4-5 Government of Alberta's established OEL for RCF

Fibres	8-hour OEL
Refractor ceramic fibres (RCF)	0.2 fibres/cc

Source: Government of Alberta. 2009. Ocupational Health and safety Code.

B.4.7 Assessment and monitoring

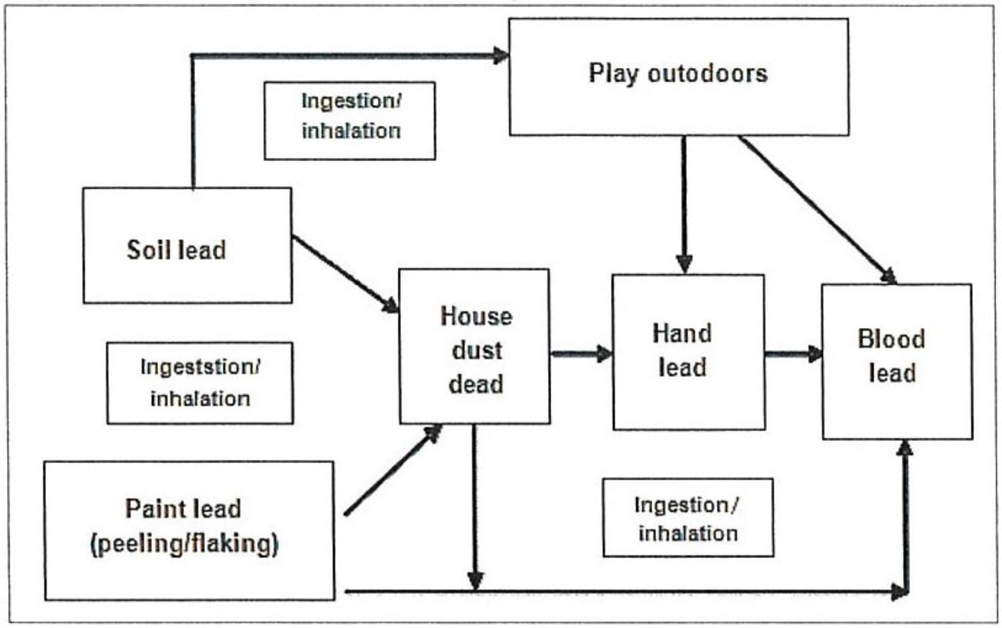
the International Labour Organization (ILO 2000) recommends that whenever assessment or monitoring is applicable it should be carried out "in accordance with the requirements of the competent authority." Adherence to this recommendation is important for occupational health and safety applications. Environmental public health professionals should also consider this recommendation when obtaining environmental samples. Standardized procedures and methodologies are available. Results are reported as fibres per millilitre of air (fibres/ml) or as weight per unit volume of air ($\mu g/m^3$) (ILO 2000). The World Health Organization has established a universally accepted occupational health and safety reference method using phase contrast optical microscopes. Another method of analysis recommended by ACGIH is the NIOSH method 7400. This method is also required by the Alberta Occupational Health and Safety Code (Government of Alberta 2009).

When using innovative methodologies, caution must be taken. New methodologies should be referenced against an established method for appropriate quality control. Kauffer and coworkers (2003) evaluated and compared two direct-reading instruments with phase contrast optical microscopy to measure the number concentration of airborne fibres. They found that the response of the instruments was highly dependent on the nature of the fibres. Moreover, proper calibration is not always feasible as services from a specialized laboratory are usually required.

B.4.8 Control and management measures

MMMF exposure is mostly an occupational health concern; little information is available about environmental exposure in community settings. Education, prevention, material selection and source control are the most effective strategies in minimizing occupational exposure. Likewise, home owners and building occupants can apply similar principles for health protection. The control measures for man-made mineral fibres (MMMF) include the prudent selection of renovation or maintenance procedures, xuch as limited sanding, cutting, and drilling of MMMF materialsm, that will reduce the release of fibrous glass, ceramic and mineral wool fibres into indoor air. In addition, exposed fibreglass insulation should not be present inside a ventilation system. Fibreglass insulation should be covered with a barrier such as an aluminized fabric covering. Routine inspection and maintenance of ventilation systems should ensure that damaged coverings are repaired and that there is no exposed insulation subject to air erosion.

Figure B.5-1 Lead exposure model for young children[1]



[1]Exposure to lead in this model can occur through both the inhalation and ingestion pathways

Source: Godish (2000), Adapted and modified From Chapter Two Inorganic Contaminants: asbestos/radon/lead, Indoor Enviornmental Quality GodishT . (2000), Lewis publishers.

B.5.6.2 Standards and regulations for lead

Health Canada's current blood lead intervention level is 10 micrograms per deciliter (μg/dL) or 0.48 micromoles per litre (μmol/L). This concentration should not be interpreted as a threshold for toxicity. For blood lead level concentrations ≥ 10 μg/dL or ≥ 0.48 μmol/L, actions are recommended to reduce lead exposure.

Health Canada, who created this guideline in 1994, began the process to review the guideline in 2011. In July 2011, Health Canada released a *Proposed Risk Management Strategy for Lead and Draft Human Health State of the Science Report on Lead.* As this guideline is used by all provinces, consultation between Health Canada and the provinces will occur through 2012 to reach a common agreement on the science and policy direction for a new guideline. The new guideline is expected in 2013. See the following links: http://www.hc-sc.gc.ca/ewh-semt/pubs/contaminants/prms_lead-psgr_plomb/index-eng.php#aes and http://www.hc-sc.gc.ca/ewh-semt/pubs/contaminants/dhhssrl-rpecscepsh/index-eng.php

Other lead exposure and lead oncentrations from other regulatory agencies and organizations include:

- **Blood lead**
  - In 1991 a blood lead level of 0.48 μmol/L (10 μg/dL) was adopted by U.S. Centers for Disease Control and Prevention (CDC) as an action level for children, making it necessary to establish environmental and educational intervention to eliminate high exposure to lead (CDC 1991). In 2012, CDC

lowered the lead action level to 0.24 µmol/L (5 µg/dL)m based on a recommendation from their Advisory Committee on Childhood Lead Poisoning and Prevention (ACCLPP) and on emerging evidence provided by various research groups (Lanphear et al. 2000, Lanphear et al. 2005, Bellinger & Needleman 2003 Canfield et al. 2003.Jusko et al. 2008). Studies have found several health effects, such as cognitive and academic skills deficits, can occur in children with blood lead levels < 0.48 µmol/L (< 10 µg/dL).

- The Australian Government through the National Health and Medical Research Council (NHMRC) recommends a blood lead level below 0.48 µmol/L (10 µg/dL) for all Australians (NHMRC 2009).
- The U.S. Centers for Disease Control and Prevention recently agreed to the recommendation from their Advisory Committee on Childhood Lead Poisoning and Prevention (ACCLPP) to cut its threshold level for defining lead poisoning in children to 0.24 µmol/L (5 µg/dL) from 0.48 µmol/L (10 µg/dL), marking the first such reduction in 20 years (ACCLPP 2012, CDC 2012a, 2012b).
- In Alberta, a worker with either a blood lead level greater than 2.5 µmol/L or symptoms diagnosed as a result of lead exposure is considered to have lead poisoning. The Director of Medical Services must be notified if a worker has a blood lead level of 2.5 µmol/L or greater. Female workers of childbearing age who are pregnant or considering becoming pregnant should be monitored. Female workers need to have a health assessment at the same frequency as other workers. However, the blood lead level should be kept below 0.5 µmol/L (Government of Alberta 2009).

- **Occupational exposure**

  OSHA (Occupational Safety and Health Administration) Lead Standard (US OSHA 1997) limits the amount of lead in the air in the workplace. Under the OSHA regulation, if any employee is exposed above the action level, the employer must set up an air monitoring program to determine the exposure level of all exposed workers. They are as follows:

  - Action level (AL) of 30 µg/m^3 of lead as an average over an eight-hour day. Action Level means employee exposure, without regard to the use of respirators.
  - Permissible exposure limit (PEL) of 50 µg/m^3 averaged over an eight-hour workday. This is the highest level of lead in the air which you may be legally exposed.
  - Under this program, the blood lead level of all employees who are exposed to lead above the action level of 30 µg/m^3 is to be determined at least every six months. A blood lead level of 1.93 µmol/L (40 µg/dL) will require a written notification and medical exam, a blood lead level of 2.90 µmol/L (60 µg/dL) is cause for medical removal from exposure.

- **Indoor lead**
  - Health Canada has not established any standards or criteria for indoor lead parameters but supports minimizing exposure by developing regulations that restrict the use of lead in consumer products.
  - The Government of Canada amended the Surface Coating Materials Regulations in 2010 to significantly lower the level of total lead in paints and other surface-coating materials, including the surface-coatings of materials applied to furniture and other articles for children, such as toys, equipment and other products, from 600 mg/kg to 90 mg/kg. This new level is equivalent to a lead concentration of 0.009% (Hazardous Products Act 2010).
  - To help protect small children, the U.S. Consumer Product Safety Commission set the acceptable limit for lead indoor paints available to the public at ≤0.009% (w/w). Products designed or intended primarily for children 12 years old and younger cannot contain more than 300 ppm of lead as of August 14, 2011 (US CPSIA 2008).
  - U.S. Department of Housing has developed the Residential Lead Hazard Standards (Toxic Substance Control Act section 403) (USEPA 2001e) for dust-lead clearances. They are as follows:
    - Floor: 431 micrograms of lead in dust per square metre ($\mu g/m^2$) or 40 micrograms of lead in dust per square foot ($\mu g/ft^2$)
    - Window sills: 2,691 $\mu g/m^2$ or 250 $\mu g/ft^2$ of dust on interior window sills
- **Ambient air**
  - The Alberta Ambient Air Quality Objective (AAQO) for lead, effective since 1999 is 1.5 $\mu g/m^3$ one hour average (AESRD 2011).
  - The Ontario Ministry of Environment (MOE 2007) set the following Ambient Air Quality Standards for Lead and Lead Compounds:
    - A 30-day ambient air quality criterion (AAQC) of 0.2 $\mu g/m^3$ of air for lead and its compounds, based on neurological effects in children
    - A 24-hour AAQC of 0.5 $\mu g/m^3$ of air for lead and its compounds, based on neurological effects in children
    - A half-hour standard of 1.5 $\mu g/m^3$ of air for lead and its compounds, based on neurological effects in children.
  - The USEPA issued a final ruling in 2008 that revised the National Ambient Air Quality Standards (NAAQS) for lead, setting the standard as 0.15 $\mu g/m^3$ rolling three- month average. However, the 1978 lead standard of 1.5 $\mu g/m^3$ as a quarterly average remained in effect until one year after an area was designated for the 2008 standard. However, in areas designated non-attainment for the 1978, the 1978 standard remains in effect until plans to attain or maintain the 2008 standard are approved (USEPA 2008).
  - The European Union set the lead health based Air Quality Standard as 0.5 $\mu g/m^3$ (annual average) (EU Environment 2012, Environmental Protection UK 2009).

D.6 Guidelines and recommended actions

D.6.1 Health Canada

Although there is no regulation that governs an acceptable level of radon in Canadian homes or public buildings including schools, hospitals, care facilities and detention centres. Health Canada and partners (2007) developed a guideline which recommends the following:

- Remedial measures should be undertaken in a dwelling whenever the average annual radon concentration exceeds 200 Bq/m^3 in the normal occupancy area.
- The higher the radon concentration, the sooner remedial measures should be undertaken.
- When remedial action is taken, the radon level should be reduced to a value as low as practicable.
- The construction of new dwellings should employ techniques that will minimize radon entry and will facilitate post-construction radon removal should this subsequently prove necessary.

Health Canada further provides recommendations on the timeline of remediation based on the radon concentration measured in a home.

Health Canada recommended actions for radon remediation

Radon concentration	Recommended action time
< 200 Bq/m^3	No action required
200- 600 Bq/m^3	Remediate within 2 years
> 600 Bq/m^3	Remediate within 1 year

Source: Health Canada. 2010. Radon: Protect Yourself and Your Family. Available at http://www.hc-sc.gc.ca/ewh-semt/radiation/radon/protect-proteger-eng.php *(Accessed on January 11, 2012)*

D.6.2 U.S. Environmental Protection Agency (USEPA)

EPA's current action level is 4 pCi/L. EPA recommends homes be fixed if the radon level is 4 pCi/L or more. Because there is no known safe level of exposure to radon, EPA also recommends that Americans consider fixing their home for radon levels between 2 pCi/L and 4 pCi/L. The average radon concentration in the indoor air of America's homes is about 1.3 pCi/L. It is this level that USEPA based its estimate of 20,000 radon-related lung cancers a year.. It is also for this simple reason that USEPA recommends that Americans consider fixing their homes when the radon level is between 2 pCi/L and 4 pCi/L.

The average concentration of radon in outdoor air is 0.4 pCi/L or 1/10th of EPA's 4 pCi/L action level. The U.S. Congress has set a long-term goal that indoor radon levels be no highe than outdoor levels. While this goal is not yet technologically achievable in all cases, the radon level in most homes today can be reduced to 2 pCi/L or below (USEPA, 2009).

USEPA recommended actions for radon remediation

Radon concentration	Recommended action time
≥4 pCi/L (about 150 Bq/m^3)	Remediation of home should be conducted.
2-4 pCi/L (75-150Bq/m^3)	Remediation of home is recommended because the radon concentration is higher than the average indoor radon concentration in the indoor air of America's homes. Most homes today can be reduced to 2 pCi/L or below with the available technologies.

Source: U.S. Environmental Protection Agency, 2009. A Citizen's Guide to Radon: The Guide to Protecting Yourself and Your Family from Radon. Available at http://www.epa.gov/radon/pdfs/citizensguide.pdf (Accessed on January 12, 2012)

D.6.3 World Health Organization (WHO)

WHO's recent studies have shown that, when exposed to a radon concentration of 100 Bq/m3, a non-smoker's risk of lung cancer by age 75 years increases by 1 in a 1000 compared to non-exposed persons (2005 press release). Therefore, WHO proposes a reference level of 100 Bq/m^3 to minimize health hazards because of indoor radon exposure. However, if this level cannot be reached under the prevailing country-specific conditions, the chosen reference level should not exceed 300 Bq/m^3, which represents approximately 10 mSv per year according to recent calculations by the International Commission on Radiation Protection (WHO, 2009).

D.6.4 The American Society of Heating, Refrigerating and Air-Conditioning Engineers

ASHRAE Standard 62.1 (ASHRAE 2010) specifies minimum ventilation rate and other measures intended to provide acceptable indoor air quality in new or existing buildings. The 2010 revision of ASHRAE 42.1 adopts the EPA's action level as the target indoor concentration for Radon.

ASHRAE's concentration of interest for radon	
4 pCi/L (about 150 Bq/m3)	Based on lung cancer, average exposure for one year.

Source: ASHRAE 42.1-2010. Table B-2 Concentration of Interest for Selected Contaminants

D.6.5 Canadian Nuclear Safety Commission (CNSC)

CNSC, formerly known as the Atomic Energy Control Board (AECB), Canada sets radiation exposure limits in relationship to nuclear facilities. CNSC sets two types of exposure limits: one for occupationally exposed persons, the other for the general public. The annual occupational exposure limit is 4 WLM. The annual exposure limit for the general public is 70 Bq/m^3. In homes and other non-occupational settings, the maximum permissible annual average concentration of radon daughters caused by the operation of a nuclear facility is 0.02 WL (radon level 148 Bq/m^3).

CNSC's permissible exposure limits	
70 Bq/m^3	Annual exposure limit for general public

Source:Canadian Centre for Occupational Health and Safety (2009), Radon in Buildings, Available at http://www.ccohs.ca/oshanswers/phys_agents/radon.html *(Accessed on January 12, 2012)*

E.2.4 Exposure limits and guidelines

Because of variances in personal sensitivities and the presence of diverse groups of moulds, it has been impossible to set different exposure limits for moulds that can be applied to protect human health. In spite of these limitations, a few studies are available regarding exposure limits and the effect of inhaled moulds on human health (Davis, 2001). However, these studies have been limited by the absence of definitive biomarkers specific to moulds. At the present time, there are no established biomarkers that can prove that an individual has been exposed to moulds although research is progressing in this area. As a result of this limitation, a definitive correlation between mould exposure and incidence of specific health effects is not possible. *The New York City Department of Health Guidelines* (2008) states that susceptibility among humans varies with the genetic predisposition, age, state of health and concurrent exposures. Based on large information gaps in this dataset, it is not possible to determine safe or unsafe levels of exposure to moulds for the general population.

It is not possible to determine safe or unsafe levels of exposure for the general public because of variation of individual susceptibility, lack of standardized and validated environmental exposure sampling methods and lack of reliable biological markers (Douwes et. al., 2003).

At the time of the writing of this manual, no work had established the specific adverse effect that occurs at the lowest level of exposure nor had a true LOAEL or NOAEL been established, or chronic respiratory exposures in animals had not been gauged. More importantly, studies have focused on spores or on individual pure mycotoxins, neither of which characterizes what people breathe in indoor spaces. Indoor exposures are a complex mixture of moulds, bacteria, fragments of both types of organisms, their multiple toxic products and biologically derived small particles, gases and other air pollutants. Effects, depending on the susceptibility o the exposed occupants and their degree of exposure, can be combinations of allergic response, inflammation and its consequences, and other toxic responses.

E.2.4.1 Health Canada

Health Canada's *Residential Indoor Air Quality Guideline – Mould* (2007) reviewed the scientific literature on moulds and health effects and found:

- Exposure to indoor mould was associated with an increased prevalence of asthma-related symptoms,such as chronic wheezing, irritation symptoms, and non-specific symptoms.
- Instillation of fungal antigens in laboratory animal studies (*Penicillium* sp. and *Aspergillus sp.*) and fungal cell components [(1->3)-ß-D-glucan] resulted in an inflammatory response in the lungs of rodents, while instillation of *Stachybotrys chartarum* spores resulted in severe histological and biochemical changes.

Health Canada concluded that mould growth in residential buildings may pose a health hazard. Health risks depend on exposure and, for asthma symptoms, on allergic sensitization. However, the large number of mould species and strains growing in buildings and the large inter-individual variability in human response to mould exposure precludes the derivation of exposure limits. Therefore, Health Canada recommends: (1) to control humidity and diligently repair any water damage in residences to prevent mould growth; and (2) to clean thoroughly any visible or concealed mould growing in residential buildings. These recommendations apply regardless of the mould species found growing in the building. Further, in the absence of exposure limits, results from tests for the presence of fungi in air cannot be used to assess risks to the health of building occupants.

E.2.4.2 U.S. Environmental Protection Agency (USEPA)

In the absence of threshold limits, in most cases if visible mould growth is present, sampling is unnecessary. In specific instances, such as cases where litigation is involved, the sources of the mould contamination is unclear, or health concerns are a problem, sampling may be considered as part of the site evaluation (USEPA, 2010).

E.2.4.3 World Health Organization (WHO)

As the relations between dampness, microbial exposure and health effects cannot be quantified precisely, no quantitative health-based guideline values or thresholds can be recommended for acceptable levels of contamination with micro-organisms. Instead, it is recommended that dampness and mould-related problems be prevented. When they occur, they should be remediated because they increase the risk of hazardous exposure to microbes and chemicals.

E.2.4.4 New York City

New York City (2008) *Guidelines on Assessment and Remediation of Fungi in Indoor Environments*, also recommends indoor air monitoring for bioaerosols and bulk sampling not be a routine component of a building investigation. Air monitoring should be limited to a number of specific goals or reasons:

- Air monitoring is required to identify and quantify fungi for medical reasons.
- Air monitoring is conducted to help localize a fungal amplifier that is eluding discovery by following a concentration gradient.
- Air monitoring may be necessary to determine if fungal contamination has spread to other areas via an HVAC system.
- Bulk or surface sampling is not recommended as a routine investigation activity. Bulk sampling and analysis may be required as part of a medical evaluation or to complete an equivocal visual inspection, e.g., sample suspect discolouration or staining.
- In addition to the above conditions, air or bulk sampling may also be performed for legal purposes.

New York City (2008) recommends that buildings with visible mould growth (alive or dead), evidence of water damage or musty odours be addressed immediately. Releases of water or other moisture control problems in the building must be stopped, water damaged areas identified and promptly dried. Mould damaged materials should be delineated and remediated following recommended procedures, described later in this chapter. Environmental sampling is **not** usually necessary to proceed with remediation of visually identified mould growth or water-damaged materials. Decisions about appropriate remediation strategies can generally be made on the basis of a thorough visual inspection. Environmental sampling may be helpful in some cases, such as to confirm the presence of visually identified

2000) because of more favourable conditions in the residential buildings than in the institutional buildings.

E.3.2 Health effects

Dust mites can trigger asthma symptoms and can cause asthma in children with no previous asthma symptoms (United States Environmental Protection Agency, 2008).

Dust mites produce allergenic proteins that are attached to sensitized cells in the air passages and cause hay fever and asthma when inhaled. These proteins come from the digestive tract of mites and are found at high levels in mite feces. Mite (fecal pellets) are usually 10 to 20 um in diameter (Tovey et al., 1981; De Blay et al., 1992, cited in Platts-Mills, 2001).

Several acute and chronic health effects have been reported among individuals exposed to dust mites. The following box shows different acute and chronic effects from exposure to dust mites (Godish, 2000; Spengler et al., 2001).

Health effects caused by exposure to dust mite allergens

Acute effects

- Acute asthmatic attacks
- Mucous membrane irritation
- Cold allergy
- Nasal passage obstruction and nasal irritation

Chronic effects

- Chronic allergic rhinitis
- Chronic asthma
- Atopic dermatitis
- Difficulty in concentrating

House dust mites significantly affect allergic adults and children by inducing asthmatic symptoms (Meijer et al., 1995). In addition to genetic susceptibility, individuals who are exposed to house dust mites in their childhood were found to be more susceptible to develop asthma (Sporik et al., 1990). House dust mites also aggravate atopic dermatitis in individuals suffering from asthma can be considered he to dust mite exposure.

A comparison of the prevalence rate of mite sensitization among asthmatics and non-asthmatics emergency-room patients in the USA showed that asthmatic individuals have a higher prevalence of mite allergen sensitization (production of IgE antibodies) than non asthmatics (Godish, 2000).

E.3.3 Exposure

The primary route of exposure to dust mites is inhalation and dermal contact. However, dust mites and dust mite allergens don't become airborne unless they are disturbed or stirred-up. Airborne dust mite levels and exposures increase significantly during indoor activities such as organizing beds, pillows and mattresses and during cleaning rooms and carpets (Godish, 2000; Spengler et al., 2001). Different studies are available on dust mite concentrations in different indoor fabric materials such as pillows and mattresses. Pillows (7.2 μg/g of dust) were found to contain a higher number of mite allergens than mattresses (6.8 μg/g of dust) (Baena-Cagnani et al., 1999).

contain up to 16 eggs. A typical egg case is 8 mm long and 5 mm high. Male cockroaches have a shorter life span than females (Godish, 2000; Barbara, 2000).

Environmental factors such as temperature and humidity can increase or decrease the developmental time of the American cockroach (Barbara, 2000). Under ordinary room temperature, the developmental time (egg to adult) averages about 600 days during which they molt at least 10 to 13 times. In one experiment, adult females lived up to 440 days at ordinary room conditions, but at 29°C, their life span was decreased to 225 days and adult males, on average, lived about 200 days. American cockroaches can also thrive in moderate winter temperatures. They are omnivorous and opportunistic feeders. In addition to decaying organic matter, they can consume a variety of things such as paper, boots, hair, bread, fruit, cloth and dead insects (Barbara, 2000).

E.4.1 Cockroach allergens

Cockroach allergens consist of fecal material, saliva and different body parts. Two major allergens that have been identified from German cockroaches are Bla g I and Bla g II (Godish, 2000). These cockroach allergens are homologous with proteins derived from other species and many of those proteins are enzymes. Bla g I and Bla g II have molecular weights of 25 KDa (Kilodalton) and 36 KDa, respectively. Cockroach allergens can be found in floor dust samples. Very limited information is available on the aerodynamic behaviour of particles that contain cockroach allergens. The aerodynamic properties of cockroach allergens are unknown although they are believed to be >10 um. It is highly unlikely that these allergens will become airborne on their own. Vacuuming and other indoor activities will readily aerosolize cockroach allergens (Godish, 2000; Spengler et al., 2001).

Cockroach allergen concentrations were analysed using monoclonal antibody assays. The measured concentrations were reported in units per gram (U/g). U.S. studies found more than 2 U/g Bla g II in floor dust in 25% to 75% of low-income houses. In highly infested houses, cockroach allergens as high as 1,000 U/g were recorded in the kitchens (Godish, 2000).

E.4.2 Health effects and sensitive or vulnerable

A comparison of the prevalence rate of cockroach sensitization among asthmatics and non-asthmatics emergency room patients in the USA showed that asthmatic individuals have a higher prevalence of cockroach allergen sensitization (production of IgE antibodies) than non asthmatics (Godish, 2000).

Exposure to German cockroach (*Blattella germanica*) allergens has been reported to cause chronic respiratory diseases such as asthma (Pomes et al., 2002; Godish, 2000). Information on the allergenicity of the American cockroach is limited.

contamination to other locations. In some residential buildings, dog allergens in floor dust samples have been found as low as 0.3 μg/g in the absence of a dog and as high as 10,000 μg/g in the presence of a dog (Godish, 2000).

According to Godish (2000), 2.3 per cent of the U.S. population is sensitive to dog allergens. It is believed that several micrograms of dog allergens can affect both adults and children and can provoke asthmatic symptoms. The presence of several types of indoor allergens can affect children and other vulnerable individuals. Sarpong and Karrison (1998) reported that children with combined sensitivity to cat, dog, dust mite and cockroach allergens can be at increased risk of severe asthma.

E.5.2 Cat allergens

There are two types of cat allergens: Fel d 1 and Fel d 2. The size of the particle that contains these allergens can vary from < 2.5 um to 10 um. Because of their small size, they can become easily airborne even in undisturbed indoor environments) and, they can remain airborne for extended periods of time (even hours (Godish, 2000). Particles that carry cat allergens appear to be very sticky. Therefore, cat allergens tend to stick to clothing during handling and grooming activities.

A single cat has the potential to release 3 μg to 7 μg of allergen per day. Fel d 1 (*Felis domesticus 1*) is the major cat allergen found in indoor air. It is an acidic glycoprotein and can be found in cat hair, skin, saliva, sebaceous glands secretions and urine. It is easily dispersed into the air during owner handling and grooming and by a cat's self-grooming licking behviour.

Carpets act as reservoirs for cat allergens. In a school environment, students who own cats can bring allergens to schools. Even if a cat is gone from a home, a past history of a cat's presence can also lead to health problems among humans. A higher concentration of airborne cat allergens can be associated with factors, such as a high number of cats and a building with a low air exchange rate.

Godish (2000) has reported an association between different cat allergen concentrations and risk of sensitization (Table E-4).

Table E-4 Risk of sensitization to cat allergens in dust samples

Concentration of cat allergens in dust samples		
< 1 μg/g	1 to 8 μg/g	> 8 μg/g
Low sensitization risk	Major sensitization risk	Major risk of causing acute asthmatic symptoms

Source: Godish (2000), In Indoor Environmental Quality, Lewis Publishers, 2001

Allergic individuals can show acute symptoms of rhinitis, conjunctivitis or wheezing within 20 minutes of exposure to cat allergen, such as after entering a cat-inhabited house (Platt-Mills, 2001, cited in Spengler et al., 2001).

- Even where its incidence among mice is highest, hantavirus infects only a tiny proportion of people who come in contact with it. However, in the few people who develop hantavirus infection, it can be fatal in one-third of the cases if left untreated.
- There is no vaccine, treatment or cure for HPS. However, early detection and medical care is extremely important and reduces the risk of death. Those who are infected may be given medication for fever and pain as well as oxygen therapy.
- The virus has existed in North America for many years but only was recognized for the first time in May 1993 in New Mexico.
- Deer mice surveys for hantavirus were done in Alberta around a decade ago. Between four and 23 per cent of mice were positive. There was no correlation between the number of mice and the number of human cases.

E.5.4.3 Health effects and symptoms

Early symptoms are similar to the flu, but can quickly develop into severe breathing problems and in some cases hantavirus infection can be fatal.

The following flu-like symptoms can result from Hantavirus pulmonary syndrome (HPS) at early infection:

- Fever
- Chills
- Muscle aches
- Headaches
- Nausea
- Vomiting

Symptoms can appear within three to 60 days after exposure. However, the average time it takes for symptoms to appear is 14 to 30 days after exposure. HPS is extremely serious since approximately 30% to 40% of cases result in death, usually within a few days of the initial symptoms appearing. Those who recover do so rapidly and regain full functioning of their lungs, but long term-effects, such as fatigue are common.

HPS can progress rapidly into serious lung complications and include the following symptoms:

- Abnormal fall in blood pressure
- Lungs fill with fluid
- Severe respiratory failure

In Canada, although the risk of exposure is low, the disease can be very severe.

The incidence of the hantavirus and the risk it poses to the public is low. However, particularly in the spring, when the weather improves and people spend more time outdoors and doing spring cleaning, remember to keep any risk to a minimum and *take precautions to avoid hantavirus infection.*

Strategies for minimizing risk of hantavirus

The only confirmed carrier of the hantavirus in Alberta is the deer mouse (reddish-brown or in some cases grey, but always with white fur on the underside of the neck, belly, feet and tail). However, it is possible that other rodents may carry the virus and it is not always easy to determine what kind of mouse one is exposed to, particularly when

- Immune system damage in older populations and smokers
- Neurological effects such as disorientation, depression, hallucinations, delirium and retrograde amnesia
- Long-term weakness, persistent headaches, chills and chronic coughing

E.6.2 Exposure

Inhalation is the primary route of exposure to Legionella aerosols generated from contaminated water, such as residential and hotel showers and HVAC/humidifier systems (Godish 2000). Although showering is a suspect activity, there is no data that supports exposure to Legionella and disease from showering (Barry, 2001; Spengler et al., 2001; Godish, 2000).

E.6.3 Guidelines

No numerical exposure or health effects guidelines were located for Legionella at the time of the writing of this manual.

E.6.4 Control measures

Several regulatory agencies such as CDC and ASHRAE have provided guidelines and recommendations to control or remediate Legionella bacteria contamination of indoor sources.

Legionella are ubiquitous in the environment. Therefore, a complete eradication of those organisms from indoor sources may not be possible (Barry, 2001, cited in Spengler et al., 2001). Periodic checking and maintenance of indoor sources is essential to minimize contamination (Barry, 2001; Spengler et al., 2001). Detection of a low level of Legionella bacteria ranging from 50 CFU/mL to 100 CFU/mL will require the setting up of an effective maintenance protocol to avoid a Legionella outbreak. CDC has developed several disinfection procedures for potable water systems and cooling towers that are contaminated with Legionella (CDC, 1994b).

E.6.4.1 Disinfection procedures for potable water systems and cooling towers

- **Potable water systems**

  Maintenance of potable water systems from Legionella contamination involves a one-time thermal disinfection process, which can be accomplished by:

  - Raising the temperature of water to 65°C (150°F) in the hot water tank
  - Flushing each water outlet for five minutes
  - Eliminating dead lines.

Cookingham and Solomon (1995) reported that allergen levels required to cause health symptoms vary greatly among individuals, being influenced by recent exposures (cited in Muilenberg 2001). Several laboratory allergy sensitivity studies have shown differences in sensitization rates in different population groups exposed to different pollen agents (Table E-8).

Table E-8 Pollen sensitization rates among population groups

Pollen agent	Population	Percentage of positive skin-prick test reaction	
		Total cohort[1] (%)	*Atopics[2] (%)*
Olive pollen	Italians	17	23
Rye grass pollen	New Zealand children	32	72
Pecan pollen	Israelis	12	25
Pellitory pollen	Florida allergy patients	Not available	20
Hemp pollen	Nebraska allergy patients	Not available	61

1.Total cohort shows a population not selected on the basis of allergy status

2. Atopics shows those individuals having hypersensitivity diseases with a familial tendency

Source: Muilenberg, M.L. (2001), Pollen in indoor air: sources, exposure and health effects, Chapter 44, in Indoor Air Quality Handbook, Spengler et al (2001), McGraw-Hill publications, 2001.

E.7.4 Guidelines

No numerical guidelines for pollen were available at the time of writing of this manual.

E.7.5 Control measures

Different proposals have been made to reduce or eliminate indoor bioaerosols, with efficiencies close to 100 per cent, basically by filtering the air with electrostatically charged activated carbon (Holmquist and Vesterberg, 1999; Kettrup and Schmidt, 1987) or using HEPA (high efficiency particulate air) filters (Billings, 1982; Cheng et. al., 1998). Nevertheless, air conditioning has been suggested as an effective means for reducing the penetration of outdoor bioaerosols into interiors (Enomoto et. al., 2004).

The National Institute of Environmental Health Sciences (NEIHS) has recommended several prevention strategies for different types of pollens including grass, ragweed and tree pollen. The following recommendations are some of the general control measures one can carry out to avoid or prevent pollen exposure (NEIHS), http://www.niehs.nih.gov/ health/topics/conditions/asthma/allergens/pollen/.

F.2.1 Guidelines

F.2.1.1 International Fragrance Association

The International Fragrance Association (IFRA) was formed in 1973 in Geneva. It originally consisted of fragrance manufacturers from Europe. Its current members are now found in Asia, Australia and the Americas. It aims at representing the collective interest of the fragrance industry worldwide and to promote the safe enjoyment of fragrance products. It has set standards and guidelines.

The product risk-assessment of IFRA is supported by its Research Institute for Fragrance Materials (RIFM) (IFRA 2012). The RIFM's work is evaluated by an independent scientific expert panel; however, the adequacy of its guidelines and standards for health protection is uncertain. The standards are divided into three categories: specification, prohibited and restricted. Readers who are interested in the standards are encouraged to refer to the IFRA website at http://www.ifraorg.org/en-us/standards_1

F.2.1.2 Environment Canada

Environment Canada has recommended limits for VOCs (volatile organic compounds) content and HVOC (high-volatility organic compounds) in different fragrance products (Table F-3). HVOC compounds have vapour pressure greater than 80 mm of Hg at 20°C. The following guidelines are not applicable to VOCs that:

- Have a vapour pressure of less than 0.1 mm of Hg at 20°C
- Consists of more than 12 carbon atoms if vapour pressure is unknown

-or-

- If vapour pressure is unknown, set a melting point above 20°C that will not sublimate

Table F-2 VOC content limit in fragrance products

VOC Content Limit in Fragrance Products	
	Content limit (weight %VOC)
Air fresheners	
• Single-phase	70
• Double-phase	0
• Liquid/pump sprays	8
• Solids/Gels	3
Hair products	
• Hairsprays	80
• Hair mousses	16
• Hair styling gels	6
Shaving creams	5
Nail Polish removers	85

Source: Environment Canada. 1999. Guidelines for Volatile Organic Compounds in Consumer Products, Accessed on May 8, 2012 from http://www.ec.gc.ca/lcpe-cepa/8B453EE9-EC824ADA-B945-5D45B04349F4/voc-eng.pdf

F.2.1.3 Health Canada

The Health Canada Cosmetics Program has developed the *Cosmetic Ingredient Hotlist* to "keep the cosmetic industry aware of new substances Health Canada considers inappropriate for cosmetic use or which require avoidable hazard labeling." The *Hotlist* is science-based and is updated a few times per year. Therefore, readers should refer to the most current "Hotlist" that is accessible at http://www.hc-sc.gc.ca/cps-spc/cosmet-person/indust/hot-list-critique/index-eng.php.

F.2.1.4 Scent Free Environment and Human Rights

Scented products are widely reported by individuals with asthma to trigger symptoms (Baldwin et al. 1995). Canadian federal and provincial laws are in place to cover the sensitive groups. For example, the Canadian Human Rights Commission states (CHRC 2007):

> *This medical condition [environmental sensitivities] is a disability and those living with environmental sensitivities are entitled to the protection of the Canadian Human Rights Act, which prohibits discrimination on the basis of disability. The Canadian Human Rights Commission will receive any inquiry and process any complaint from any person who believes that he or she has been discriminated against because of an environmental sensitivity. Like others with a disability, those with environmental sensitivities are required by law to be accommodated.*
>
> *The CHRC encourages employers and service providers to proactively address issues of accommodation by ensuring that their workplaces and facilities are accessible for persons with a wide range of disabilities.*
>
> *—Canadian Human Rights Commission (2007)*

apartment buildings housing a dry-cleaning facility. Air sampling in 12 residences from eight apartment complexes detected elevated levels of tetrachloroethylene, which exceeded the ATSDR minimal risk level (MRL) for chronic inhalation exposure of 0.27 mg/m^3 or 40 ppb. The MRL for acute inhalation exposure is 1.36 mg/m^3 or 0.2 ppm. The mean tetrachloroethylene concentration in these residential sites was 2.0 mg/m^3 with a range from 0.47 mg/m^3 to 4.2 mg/m^3. The results show that people in those residences were exposed to tetrachloroethylene concentrations that exceeded minimal risk levels. The study concluded that residents who live in the buildings that house dry-cleaners may be exposed to tetrachloroethylene concentrations that are a public health concern.

F.3.1 Limits and guidelines

F.3.1.1 Environment Canada

Table F-4 presents the VOC content limits for various cleaning products that are often used in various household activities.

Table F-4 VOC Content limits for cleaning products

VOC content limit	
Bathroom and tile cleaners	***Content limit (weight %VOC)***
Aerosols	7
All other forms	5
Dusting aids	
Aerosols	35
All other forms	7
Fabric protectants	75
Floor polishes/waxes	
Products for flexible flooring materials	7
Products for non resilient flooring	10
Wood Floor Wax	90
Furniture maintenance products	25
General purpose cleaners	10
Glass cleaners	
Aerosols	12
All other forms	8
Laundry pre-wash	
Aerosol/solids	22
All other forms	5
Laundry starch products	5
Oven cleaners	
Aerosol/pump sprays	8
Liquids	5

Source: Guidelines for Volatile Organic Compounds in Consumer Products (Draft), Canadian Environmental Protection Act (CEPA) 1999, Environment Canada 1999

Table F-5 Emission rates and indoor air concentrations of chemicals from office equipment and electronic products

Office equipment	Contaminants	IAQ/emission rate	Pollution prevention options	Comments
Dry-process photocopy	Machines	VOCs, respirable particulate (toner powder) and ozone (O_3)-O_3: 40 □g/copy (average), with a peak conc. of 131 µg/copy, 0-1350 □g/min and average 259 □g/min	-Particulates: 0.001 □g/m3 room concentration of carbon black; 90-460 □g/m3 in exhaust air	-TVOC: 0.5 to 16.4 □g/sheet from paper . Lower voltage to reduce O_3 (charged rollers), toner reformulation, improved transfer efficiency, low er maintenance machines, lower fuser temperature, changes in toner particle size, low emitting components. Large units of machines should have dedicated HVAC systems.
Wet-process photocopy machines	VOCs and O_3	TVOC: 25g/h, 0.241 g/copy, observed high room concentration of 64 mg/m^3; 4150 mg/m^3 in exhaust air	Solvent reformulation; pressure fusing, decrease voltage, low-emitting components	
Laser printers	VOCs, respirable particulates and O_3	-O_3: 100-4000 µg/m^3 room concentration; 438 µg/min (average); 100 µg/min (with filter) -Respirable particulates: 60 µg/min -TVOC: 2.0-6.5 µg/sheet	Same as for dry-process photocopying machines	
Ink/bubble jet printers	VOCs and O_3	No published data up to 1994	Solvent reformulation, low emitting components	Primary use – personal home based
Impact Printers	VOCs	-TVOC: 0.7 – 1.0 µg/sheet from paper -No data on emissions from operation	Low-emitting components reformulated inks	Relatively low emission rates; generally used for personal printing purposes and home use
Fax Machines	O_3 and VOCs	-No published emission rate or IAQ data up to 1994	Same as for dry-process photocopying machines	Found in most offices
Computer terminals	O_3 and offgasing VOCs	-Limited published data until 1994. -TVOC: 175 ug/hour (max) from VDT drops quickly within 300 hours of operating time	Low emitting materials and/or lower voltage, alternative materials for cards used in integrated circuit boards	Relatively low emissions when compared to other sources. Approximately 10 million units sold annually (based on 1994 data)
Blueprint machines (dyeline)	Ammonia, carbon monoxide, methanol, ethanol, trinitrofluorene, trichloroethane	-1-40 ppm ammonia in breathing zone of operator, 8.2 ppm (average)	CAD/alternative technologies, improved maintenance	Older technology; therefore, losing market share to CAD/alternative technologies
Digital duplicator	VOCs-petroleum solvent and ethylene glycol	Combined VOCs: 20 mg/page	Lower VOC inks; can be replaced with photocopiers but not necessarily a pollution prevention approach	Limited market share of this technology
Spirit duplicator	Methanol	Breathing zone concentrations of 40-635 ppm; 195-3,000 ppm with no ventilation, 80-1,300 ppm with ventilation, and 9-135 ppm with enclosure and ventilation	Replacement with photocopiers (not necessarily a pollution prevention approach)	Limited market share of this technology (a very few schools and institutions)
Mimeo-graph machines	Hydrotreated heavy and light naphthenic distillates	-Heavy napthenic distillate: 30 mg/page -10 mg/page light napthenic distillate	Ink reformulation, replacement with photocopiers or other technologies (not necessarily a pollution prevention approach)	Limited market share of this technology
Plotters	VOCs	-No published emission rate or IAQ data (up to 1994)	Low-emitting components, reformulated inks	Limited market share, 250,000 a year worldwide (up to 1994)

Source: Office Equipment: Design, Indoor Air Emissions and Pollution Prevention Opportunities, Project Summary, Air and Energy Engineering Research Laboratory, Research Triangle Park, NC 27711, United States Environmental Protection Agency (1995)

Table F-6 Chemicals from different office equipment

Office equipment	Contaminants	IAQ/emission rate	Pollution prevention options	Comments
Dry-process photocopy machines	VOCs, respirable particulate (toner powder) and ozone (O_3)	-O_3: 40 μg/copy (average), with a peak conc. of 131 μg/copy, 0-1350 μg/min and average 259 μg/min -Particulates: 0.001 μg/m^3 room concentration of carbon black; 90-460 μg/m^3 in exhaust air -TVOC: 0.5 to 16.4 μg/sheet from paper	Lower voltage to reduce O_3 (charged rollers), toner reformulation, improved transfer efficiency, low maintenance machines, lower fuser temperature, changes in toner particle size, low emitting components	Large units of machines should have dedicated HVAC system
Wet-process photocopy machines	VOCs and O_3	TVOC: 25g/h, 0.241 g/copy, observed high room concentration of 64 mg/m^3; 4150 mg/m^3 in exhaust air	Solvent reformulation; pressure fusing, decrease voltage, low-emitting components	
Laser printers	VOCs, respirable particulates and O_3	-O_3: 100-4000 μg/m^3 room concentration; 438 μg/min (average); 100 μg/min (with filter) -Respirable particulates: 60 μg/min -TVOC: 2.0-6.5 μg/sheet	Same as for dry-process photocopying machines	
Ink/bubble jet printers	VOCs and O_3	No published data up to 1994	Solvent reformulation, low emitting components	Primary use – personal home based
Impact printers	VOCs	-TVOC: 0.7 – 1.0 μg/sheet from paper -No data on emissions from operation	Low-emitting components reformulated inks	Relatively low emission rates; generally used for personal printing purposes and home use
Fax machines	O_3 and VOCs	-No published emission rate or IAQ data up to 1994	Same as for dry-process photocopying machines	Found in most offices
Computer terminals	O_3 and offgasing VOCs	-Limited published data until 1994. -TVOC: 175 ug/hour (max) from VDT drops quickly within 300 hours of operating time	Low emitting materials and/or lower voltage, alternative materials for cards used in integrated circuit boards	Relatively low emissions when compared to other sources. Approximately 10 million units sold annually (based on 1994 data)
Blueprint machines (dyeline)	Ammonia, carbon monoxide, methanol, ethanol, trinitrofluorene, trichloroethane	-1-40 ppm ammonia in breathing zone of operator, 8.2 ppm (average)	CAD/alternative technologies, improved maintenance	Older technology; therefore, losing market share to CAD/alternative technologies
Digital duplicator	VOCs-petroleum solvent and ethylene glycol	Combined VOCs: 20 mg/page	Lower VOC inks; can be replaced with photocopiers but not necessarily a pollution prevention approach	Limited market share of this technology
Spirit duplicator	Methanol	Breathing zone concentrations of 40-635 ppm; 195-3,000 ppm with no ventilation, 80-1,300 ppm with ventilation and 9-135 ppm with enclosure and ventilation	Replacement with photocopiers (not necessarily a pollution prevention approach)	Limited market share of this technology (a very few schools and institutions)
Mimeo-graph machines	Hydrotreated heavy and light naphthenic distillates	-Heavy napthenic distillate: 30 mg/page -10 mg/page light napthenic distillate	Ink reformulation, replacement with photocopiers or other technologies (not necessarily a pollution prevention approach)	Limited market share of this technology
Plotters	VOCs	-No published emission rate or IAQ data (up to 1994)	Low-emitting components, reformulated inks	Limited market share, 250,000 a year worldwide (up to 1994)

Source: Information summarized from Indoor Environmental Quality, Chapter 7, Thad Godish (2000), Lewis publishers

Table F-7 Chemicals emitted from photocopied, laser-printed and matrix-printed paper, and toner powders

Compound	Photocopied papers	Laser Printed Papers	Matrix-Printed papers
Hexane	Detected in paper	Not detected	Not detected
1,1-Dichloro-1-nitroethane	Detected in paper	Not detected	Not detected
Benzene	Detected in paper and toner powder	Detected in paper and toner powder	Detected in paper
Octene (isomer)	Detected in paper	Not detected	Not detected
Pentanal	Detected in paper and toner powder	Not detected	Not detected
Trichloroethane	Detected in paper and toner powder	Detected in paper and toner powder	Not detected
1-Butanol	Detected in paper and toner powder	Detected in paper and toner powder	Detected in paper
Toluene	Detected in paper and toner powder	Detected in paper and toner powder	Detected in paper
Pyridine	Detected in paper and toner powder	Not detected	Not detected
4-Methyl-2-pentanone	Detected in paper and toner powder	Not detected	Not detected
Hexanal	Detected in paper	Detected in paper	Detected in paper
C4-Cyclohexane isomers	Detected in paper and toner powder	Detected in toner powder	
1-Butyl ether	Detected in paper and toner powder	Detected in paper and toner powder	Detected in paper
m- and p-Xylene	Detected in paper and toner powder	Detected in paper and toner powder	Detected in paper
o-Xylene	Detected in paper and toner powder	Detected in paper and toner powder	Detected in paper
Styrene	Detected in paper and toner powder	Detected in paper and toner powder	Detected in paper
1-Butyl acrylate	Detected in paper and toner powder	Detected in paper and toner powder	Not detected
2-Phenylpropane	Detected in paper and toner powder	Detected in paper and toner powder	Detected in paper
3-Heptanol	Detected in paper and toner powder	Not detected	Not detected
1-Phenylpropane	Detected in paper and toner powder	Detected in paper and toner powder	Detected in paper
Ethyl Toluene (isomers)	Detected in paper and toner powder	Detected in paper and toner powder	Detected in paper
3-Ethoxy-3-ethyl-4,4-dimethylpentane	Detected in paper and toner powder	Not detected	Not detected
1-Butyl methacrylate	Detected in paper and toner powder	Not detected	Not detected
Benzaldehyde	Detected in paper and toner powder	Detected in paper and toner powder	Detected in paper
Diethylbenzene isomers	Detected in paper	Detected in paper and toner powder	Detected in paper
2-Ethyl-1-hexanol	Detected in paper and toner powder	Detected in paper and toner powder	Detected in paper
2-Ethylhexyl acetate	Detected in toner powder	Detected in paper and toner powder	Not detected
2,2-Azo-bis-isobutyronitrile	Detected in paper and toner powder	Detected in paper and toner powder	Not detected
2-Ethylhexyl acrylate	Detected in paper and toner powder	Detected in paper and toner powder	Not detected
Methylbiphenyl	Detected in toner powder	Detected in paper	Not detected

G.3 Ambient (outdoor) air

Ambient (outdoor) air pollution is the result of emissions from various point or stationary area and mobile sources that can variously affect a diverse geographic range. These effects can range from localized effects at the neighbourhood or community level, to transboundary pollution from other provinces, countries or continents. Although ambient air pollution is generally regarded as originating from anthropogenic sources, it can also result from naturally occurring events, such as forest fires and volcanic eruptions (Godish, 2000).

Outdoor air can play a significant role in influencing the quality of indoor air. In most inhabited spaces there is a continuous exchange of air with the outside. For example, most of the ozone in homes comes in from outside. The level of ozone indoors is generally lower than the level outside the home (Health Canada, 2012). Outdoor PM is a significant contributor to the level of $PM_{2.5}$ indoors. In general, the indoor and outdoor (I/O) ratios for $PM_{2.5}$ are smaller than one, indicating that indoor concentrations are largely determined by outdoor sources (Health Canada, 2011; Wallace, 1996; Wallace *et. al.*, 2006).

Environment Canada (2012) categorizes air pollutants into four groups:

- **Criteria air contaminants** (CACs) (e.g. SO_2, NO_x, and VOCs)

  This group of air pollutants can cause air problems, such as smog and acid rain. They are produced in varying quantities by a number of sources, including the burning of fossil fuels. CAC, in particular, refer to a group of pollutants that include sulphur oxides (SO_x); nitrogen oxides (NO_x); particulate matter (PM); volatile organic compounds (VOC); carbon monoxide (CO); and ammonia (NH_3).

  In addition, ground-level ozone (O_3) and secondary particulate matter (PM) are often referred to among the CACs because both ground-level ozone and secondary particulate matter are byproducts of chemical reactions between the CAC.

- **Persistent organic pollutants** (POPs) (e.g. dioxins and furans)

  This group of air pollutants are a collection of pollutants that can last in the environment for long periods of time and are capable of travelling great distances. Similar to heavy metals, POPs are of particular concern because they can enter the food supply, bioaccumulate in body tissues and have significant effects on human health and the environment, even in low concentrations.

- **Heavy metals** (HMs) (e.g. mercury)

  This group of air pollutants include basic metal elements, such as mercury and lead. This group of pollutants can be transported by the air and enter our water and food supply. Although trace amounts of some metals are needed by our body, heavy metals are poisonous in low concentrations and can bioaccumulate in body tissues.

- **Toxics** (e.g. benzene)

  This group of air pollutants form a broad category of pollutants that are poisonous or toxic to human health and the environment. Although this category has some overlap with the other types of air pollutants presented here, such as CACs, HMs

Table G-5 Alberta Ambient Air Quality Objectives as of April 2011

Substance	µg m^{-3}	ppbv	Basis	Effective/Review Date
Acetaldehyde				
1-hour average	90	50	Adopted from Texas	1999
Acetic acid				
1-hour average	250	102	Adopted from Texas	1999
Acetone				
1-hour average	5,900	2,400	Adopted from Texas	1999, reviewed 2005
Acrylic Acid				January 1, 2004
1-hour average	60	20	Adopted from Texas	
Annual Average	1.0	0.34	Adopted from California	
Acrylonitrile				January 1, 2004
1-hour average	43	19	Adopted from Texas	
Annual Average	2	0.9	Adopted from California	
Ammonia				1976, reviewed 2004
1-hour average	1400	2000	Odour perception	
Arsenic				May 1, 2005
1-hour average	0.1	-	Adopted from Texas	
Annual Average	0.01	-	Adopted from Texas	
Benzene				1999
1-hour average	30	9.0	Adopted from Texas	
Benzo[a]pyrene				June 1, 2009
Annual average	0.30 ng m^{-3}	2.9×10^{-5}	Chronic and carcinogenic human health effects	
Carbon disulphide				1999, reviewed 2005
1-hour average	30	10	Odour threshold	
Carbon monoxide				1975
1-hour average	15,000	13,000	Oxygen carrying capacity of blood	
Annual Average	6,000	5,000		
Chlorine				1999
1-hour average	15	5.0	Adopted from Texas	
Chlorine Dioxide				1999
1-hour average	2.8	1.0	Adopted from Texas	
Chlorine				1999

Substance	µg m-3	ppbv	Basis	Effective/Review Date
1-hour average	15	5.0	Adopted from Texas	
Chromium				1999
1-hour average	1	-	Adopted from Texas	
Cumene				1999
1-hour average	500	100	Adopted from Texas	
Dimethyl ether				1999
1-hour average	19,100	10,100	Adopted from Texas	
2-Ethylexanol				May 1, 2005
1-hour average	600	110	Adopted from Ontario	
Ethylbenzene				May 1, 2005
1-hour average	2000	460	Adopted from Texas	
Ethyl Chlorofomate				1999
1-hour average	0.57	0.13	Stack emission limits	
Ethylene				January 1, 2004
1-hour average	1,200	1,050	Crop yield	
3-day Average	45	40	Crop yield	
Annual mean	30	26	Conifers and perennials	
Ethylene oxide				1999
1-hour average	15	8.0	Adopted from Texas	
Formaldehyde				1999, reviewed 2007
1-hour average	65	53	Adopted from Texas	
n-Hexane				August 1, 2008
1-hour average	21,000	5,960	Derived from 24-hour California objectiv	
24-hour average	7,000	1,990	Adopted from California	
Hydrogen chloride				1999
1-hour average	75	50	Adopted from Texas	
Hydrogen fluoride				1999, reviewed 2009
1-hour average	4.9	6.0	Adopted from Texas	
Fluoride content in forage-dry weight basis			Adopted from Ontario	1999
30-dayr average	35 µg g-1		April 1 to October 31	
Average for any single 30-day period	80 µg g-1		April 1 to October 31	

Average for two consecutive month	60 µg g^{-1}		April 1 to October 31	
Hydrogen sulphide				1975
1-hour average	14	10	Odour perception	
24-hour average	4	3		
Isopropanol				May 1, 2005
1-hour average	7,850	3,190	Adopted from Texas	
Lead				1999
1-hour average	1.5	-	Adopted from Texas	
Manganese				1999
1-hour average	2	-	Adopted from Texas	
Annua average	0.2	-	Adopted from Texas and California	
Methanol				1999
1-hour average	2,600	2,000	Adopted from Texas	
Methylene bispheny diisocyanate				1999
1-hour average	0.51	0.050	Adopted from Texas	
Monoethylamine				1999
1-hour average	1.19	0.645	Stack emission limits	
Nickel				May 1, 2005
1-hour average	6	-	Adopted from California	
Annual average	0.05	-	Adopted from California	
Nitrogen dioxide				1975, reviewed 2009
1-hour average	300	159	Respiratory effects	
Annual average	45	24	Vegetation	
Ozone (ground level)				1975, reviewed 2007
1-hour daily maximum	160	82	Pulmonary function	
Particulate Matter				
Fine-2.5 microns or less				2007
24-hour average	30	-	Canada Wide Standard	
Total suspended				1975
24-hour average	100		Pulmonary effects	
Annual geometric mean	60			

Pentachlorophenol				November 1, 2004
1-hour average	5.0	0.44	Adopted from Texas	
Annual average	0.5	0.04	Adopted from Texas	
Phenol				1999
1-hour average	100	26.0	Adopted from Ontario	
Phosgene				1999
1-hour average	4	1	Adopted from Texas	
Propylene oxide				January 1, 2004
1-hour average	480	200	Adopted from Oklahoma	
Annual average	30	13	Adopted from California	
Styrene				1999
1-hour average	215	52.0	Adopted from Texas	
Sulphur dioxide				1975, reviewed 2008
1-hour average	450	172	Pulmonary function Adopted from European Union-human health	
24-hour average	125	48.0		
30-day average	30	11		
Annual average	20	8.0	Adopted from European Union-ecosystems	
Sulphuric acid				1999
1-hour average	10	2.5	Adopted from Texas	
Toluene				May 1, 2005
1-hour average	1,880	499	Adopted from Texas	
24-hour average	400	106	Adopted from Michigan and Washington	
Xylenes				May 1, 2005
1-hour average	2,300	530	Adopted from Ontario	
24-hour average	700	161	Adopted from California	
Vinyl Chloride				1999
1-hour average	130	51	Adopted from Texas	

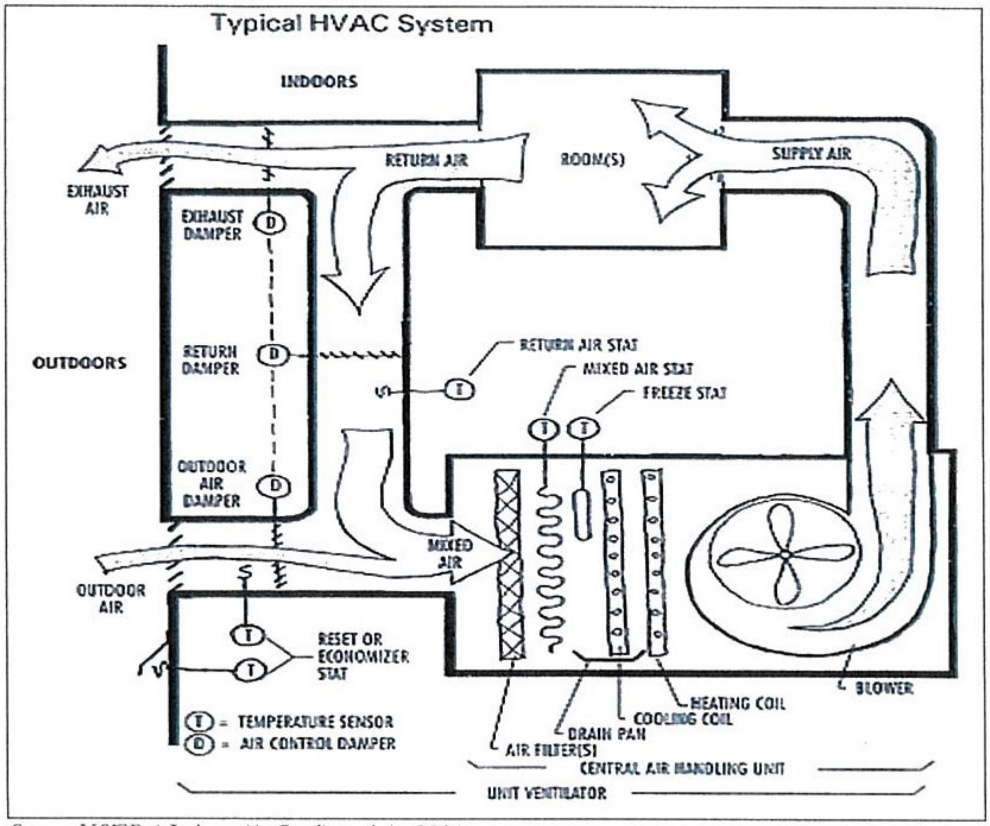
Note: $\mu g\ m^{-3}$ is the weight, in micrograms, of the substance in on cubic meter of air.
Standard condition of 25°C and 101.325 kPa are used as the basis for conversion from $\mu g\ m^{-3}$ to ppbv (parts per billion by volume) or from $mg\ m^{-3}$ to ppmv (parts per million by volume)
Underscore shows this digit is the last significant figure in the number e.g. 100 has two significant figures.
The lease significant figure is underlined to indicate calculation accuracy when converting from one unit to the other (e.g. $\mu g\ m^{-3}$ to ppbv). These numbers do not indicate reporting accuracy or precision.

Sources: Alberta Environment and Water (2011),
http://environment.gov.ab.ca/info/library/5726.pdf

Appendix Q:

Government of Alberta, 2012, Environmental Public Health Indoor Quality Manual, Schematic of a Typical HVAC System

Figure H-20: Schematics of a typical HVAC system



Source: USEPA Indoor Air Quality website 2001 http://www.epa.gov/iaq/schools/tfs/graphics/hvacsystem.jpg *Accessed June17, 2002*

The following moisture-loving species of fungi are common inhabitants of cooling coils and drain pans. Table H-10 presents a list of microbes and microbial materials found in dirty HVAC systems (Yang, 1999).

- *Acremonium spp.*
- *Aureobasidium pullulans*
- *Exophiala spp.*
- Yeasts
- *Phoma spp.*
- *Sporobolomyces spp.*
- *Rhodotorula* spp.

Appendix R:

Government of Alberta, 2009, Employment and Immigration, Indoor Air Quality Toolkit,

Standards and Guidelines

Section 4: Standards and Guidelines

This section summarizes the existing regulations, standards and guidelines that can help Alberta workplaces address IAQ issues. It is important to understand that most IAQ standards and guidelines are established to ensure the comfort of workers. So these values tend to be lower than regulatory values that are set to protect workers from possible health based hazards.

Regulations cite values that must be complied with under the law. In Alberta, the regulatory limits are called occupational exposure limits (OELs). OELs are established for health-based reasons.

Standards are set by special organizations with expertise but are not legally binding unless cited within a regulation. The IAQ values cited in standards are useful as a guide for workplaces where IAQ and comfort is a concern.

Guidelines are recommended approaches or values that are useful but not mandatory.

Various air quality resources are cited that relate to either indoor air quality, outdoor environmental standards, or workplace OELs for protecting the health of workers.

Thermal Comfort (Temperature / Humidity)

A common IAQ concern is the 'thermal comfort' of workplace occupants. Thermal comfort means that when surveyed, a substantial majority (greater than 80%) of occupants report that they are "comfortable".

Changes in seasonal outdoor environments and occupant clothing have an impact on perceived comfort levels. ASHRAE recommends the following acceptable temperature values based on occupant clothing and relative humidity levels.

Temperature / Humidity Ranges for Comfort

Conditions	Relative Humidity	Acceptable Operating Temperatures °C	°F
Summer (light clothing)	If 30%, then	24.5 - 28	76 - 82
	If 60%, then	23 - 25.5	74 - 78
Winter (warm clothing)	If 30%, then	20.5 - 25.5	69 - 78
	If 60%, then	20 - 24	68 - 75

Source: Adapted from ASHRAE 55-2004 (reference 18)

The Canadian Standards Association (CSA) also recommends similar temperature ranges for summer and winter. CSA Standard Z412 Guideline for Office Ergonomics [reference 36] recommends that for summer temperatures be from 23-26 °C, while in winter temperatures be from 20-23.5 °C. These temperature ranges are based on a relative humidity of 50%.

Thermal comfort is also affected by drafts and temperature differences. Drafts that are caused by excessive air movement can be minimized by maintaining air velocity below 0.2 m/s (40 fpm) and by directing air supply away from occupants. Maintain workplace airflow so that temperature differences between the head and feet of occupants is not greater than 3°C. ASHRAE 55-2004 - [reference 18]

Humidity/Moisture

Relative humidity levels below 20% are associated with increased discomfort and drying of the mucous membranes and skin, which can lead to chapping and irritation, and increases in static electricity. During very cold outdoor conditions, which are common in Alberta winters, humidity levels need to be reduced below 30% in order to avoid condensation on walls and windows. Condensation can lead to the development of moulds and fungi.

The following table identifies the practical relative humidity level that can be achieved based on various low outdoor temperatures.

Outdoor Temperature °C	Relative Humidity %
- 35	20
>0	30
any	60% maximum
In winter months, humidity may need to be reduced below 30% to avoid condensation.	

Adapted from Indoor Air Quality Guideline, Alberta Infrastructure (reference 16)

Other Parameters

Standards and Guidelines		
IAQ Issue	**Limits or Values**	**Cited**
Carbon Dioxide * (CO_2)	Less than 800 ppm	(1)
	1050 ppm (~300 ppm above outdoor levels)	(4)
	5000 ppm; 9000 mg/m^3 (8-hr)	(3)
Carbon Monoxide	Less than 5 ppm	(1)
	25 ppm or 29 mg/m^3 (8-hr)	(3)
	5 ppm or 6 mg/m^3 (8-hr)	(5)
Vehicle Exhaust	Refer to components such as Nitrogen dioxide, Sulfur dioxide, Carbon dioxide.	

Nitrogen Dioxide	0.3 ppm	(1)
	0.212 ppm or 0.4 mg/m^3	(5)
	3 ppm or 5.6 mg/m^3 (8-hr)	(3)
Sulfur Dioxide	0.3 ppm	(1)
	0.172 ppm or 0.45 mg/m^3	(5)
	2 ppm or 5.2 mg/m^3 (8-hr)	(3)
VOCs	5 mg/m^3	(CMHC)
	Keep specific contaminants below one-tenth of their OEL	(1)
Formaldehyde	0.10 ppm	(1)
	0.053 ppm (1-hr)	(5)
	0.75 ppm or 0.92 mg/m^3 (8-hr)	(3)
	0.04 ppm or 0.05 mg/m^3	(4)
Dust / particulates	0.1 mg/m^3 total dust	(1)
	0.1 mg/m^3 total suspended particulates	(5)
	10 mg/m^3 total particulate 3 mg/m^3 respirable particulate	(3)
	0.015 - 0.050 mg/m^3 respirable fraction of dust (fine)**	(7)
Lighting	Office: 500-750 Lux (maintained) Computer: 300-500 Lux (maintained)	(1)
	500-300 Lux horizontal (computer use - intermittent to intensive) 500 Lux (filing or mail sorting rooms) Adjust for aging workers, tasks, reduce glare	(6)
Noise (background)	48 dBA (general office area) 40-45 dBA (board rooms, private offices)	(5)
	50 dBA (call centres) 45-48 dBA (open plan offices, private offices) 35 dBA (conference rooms, executive offices)	(6)
Mould	Indoor air should reflect similar species but lower quantities than outdoor air 150 cfu/m^3 (3+ outdoor fungi species) >50 cfu/m^3 (only 1 species other than Cladosporium or Alternaria) up to 500 cfu/m^3 (summer if species primarily Cladosporium or other tree/leaf fungi)	(CMHC)
Allergens/ Tobacco Smoke	Limit or avoid exposures to fragrances, cigarette smoke, and exposures to dander-producing animals and insects.	(1)
Radon	200 Bq/m^3 (proposed)	(8)
Odours	Acceptable to > 80% occupants. Monitor CO_2 concentrations* (alternative to monitoring odours)	(7)

* CO_2 is often used to check the adequacy of the ventilation rate

** Respirable dust particles can be inhaled into the lungs

See Glossary definitions for:

Bq/m³ – Becquerel per cubic metre of air – a measurement of radioactivity
cfu/m³ – Colony forming unit of mould per cubic metre of air sampled
dBA – Decibels measure sound levels, with a weighting to approximate human hearing
Lux – A measurement of lighting level. The light of a candle at 1 foot is 10 Lux, while a sunny day outdoors is 32,000 Lux
mg/m³ – Milligrams per cubic metre of air
OEL – Occupational exposure limit reflects a concentration of a chemical in air
ppm – Parts per million reflecting a concentration of a chemical gas or vapour in air
TWA – Time weighted average for an 8-hour workday

Cited References of Air Quality Information

1. Alberta Infrastructure Indoor Air Quality Guideline

An interdepartmental committee on IAQ chaired by Alberta Infrastructure prepared this guideline for the Government of Alberta facilities. [reference 16]

2. Alberta Occupational Exposure Limits

The Alberta Occupational Exposure Limits (OEL) cited in the Occupational Health and Safety (OHS) Code (Schedule 1) reflect legal maximum allowable airborne limits for various workplace contaminants. The limits are based in part on the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs)® which are modified from time to time. These limits are based on protecting workers. Especially sensitive individuals may be affected at lower exposure values. [reference 17]

It should be noted that OELs are higher than actual airborne contaminant levels found in most office type workplaces. A common practice cited by the Alberta Indoor Air Quality Guideline is to use one-tenth of the OEL as an air quality guideline for office and related settings. Three types of limits are recommended: limits for 8-hour workdays, short-term exposure limits (15-minutes) or ceiling (not to be exceeded) limits.

3. ASHRAE Standard 55-2004

The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) publish IAQ standards. Thermal Environmental Conditions for Human Occupancy – ASHRAE Standard 55-2004 recommends temperature, relative humidity, air speed and factors such as seasonal clothing. [reference 18]

4. Health Canada Residential Indoor Air Quality Guideline

A recent guideline for formaldehyde is intended for residential exposures that are of a 24-hour nature. It is used for comparison to office workplaces. [reference 23]

Appendix S:

Government of Alberta, June 2006 (Revised June 2007), Alberta Infrastructure, Indoor Air Quality Guidelines, Appendix 3

Appendix 3 – Indoor Air Quality and Comfort Parameters

These parameters are intended to provide employees with a comfortable and healthy indoor work environment and should be applied by individuals who are trained to conduct IAQ investigations and interpret the results (i.e. technical/professional resources in Appendix 2).

Temperature(1)	22°C with a 2°C upswing at peak outdoor design temperature (summer) in air-conditioned buildings.
Relative Humidity(1)	20% at outdoor temperature of -35°C 30% at outdoor temperature >0°C 60% maximum Note: May not be achievable in some buildings due to design limitations.
Carbon Dioxide(1)	800 ppm(2)
Carbon Monoxide(1)	5 ppm(2)
Total Dust	100 ug/m^3 (3)
Total Volatile Organic Compounds	5 mg/m^3 (3)
Formaldehyde	0.10 ppm
Nitrogen Dioxide	0.3 ppm(1)
Asbestos	0.05 f/cc(1)
Ozone	0.01 ppm
Radon	150 Bq/M^3
Office Lighting	500 – 750 Lux (maintained)
Computer Lighting	300 – 500 Lux (maintained)
Background Mechanical Noise Levels - General office area - Private office – Board Rooms	48 dBA 45 dBA 40 dBA
Airborne Fungi (Health Canada Guidelines)	150 CFU/ m^3 (3 or more species reflective of outdoor flora) 50 CFU/ m^3 (only one species other than cladosporium or alternaria) Up to 500 CFU/m^3 (summer if species is primarily Cladosporium or other tree/leaf fungi). **The indoor air should normally be qualitatively similar but quantitatively lower than outdoor air.**

Notes:

(1) Comfort parameters

(2) The above listed levels were developed from the Occupational Exposure Limits. For substances other than those listed above, a level of 1/10th of the Occupational Exposure Limit as identified in Table 2, Schedule 1 of the Alberta Occupational Health and Safety Code, should be used as a guideline.

(3) References used include applicable Health Canada guidelines, comfort levels established by the American Society of Heating Refrigerating and Air Conditioning Engineers (ASHRAE), Alberta Infrastructure and Transportation's Technical Design Requirements for Alberta Infrastructure Facilities.

(4) Units of measurement:
- ppm = parts per million
- ug/m3 = micrograms per cubic meter
- mg/m3 = milligrams per cubic meter
- f/cc = fibers per cubic centimeter
- Bq/M3 = becquerel per cubic meter of air

Appendix T:

Government of Alberta, 2012, Environmental Public Health Indoor Quality Manual, Phases, Questions and Walk-Through Guidelines

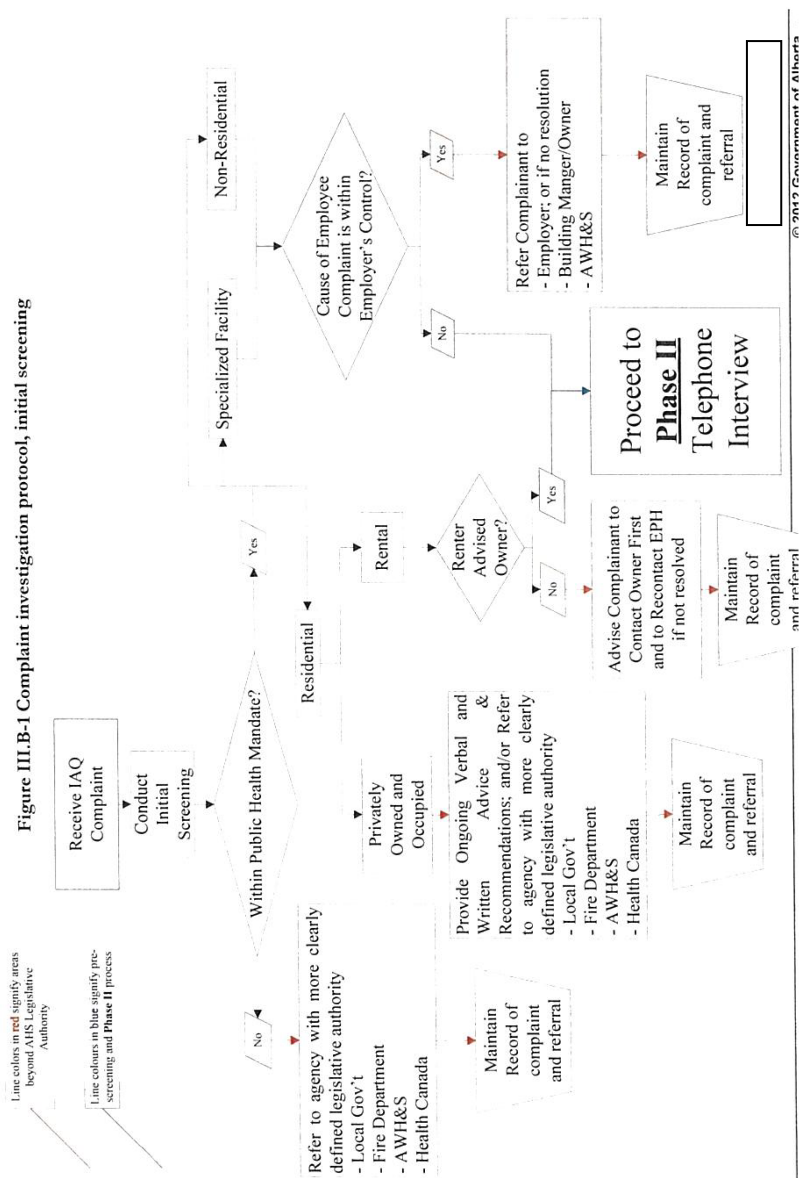


Figure III.B-1 Complaint investigation protocol, initial screening

Figure III.B-2 Phase II – IAQ Complaint investigation protocol, telephone interview

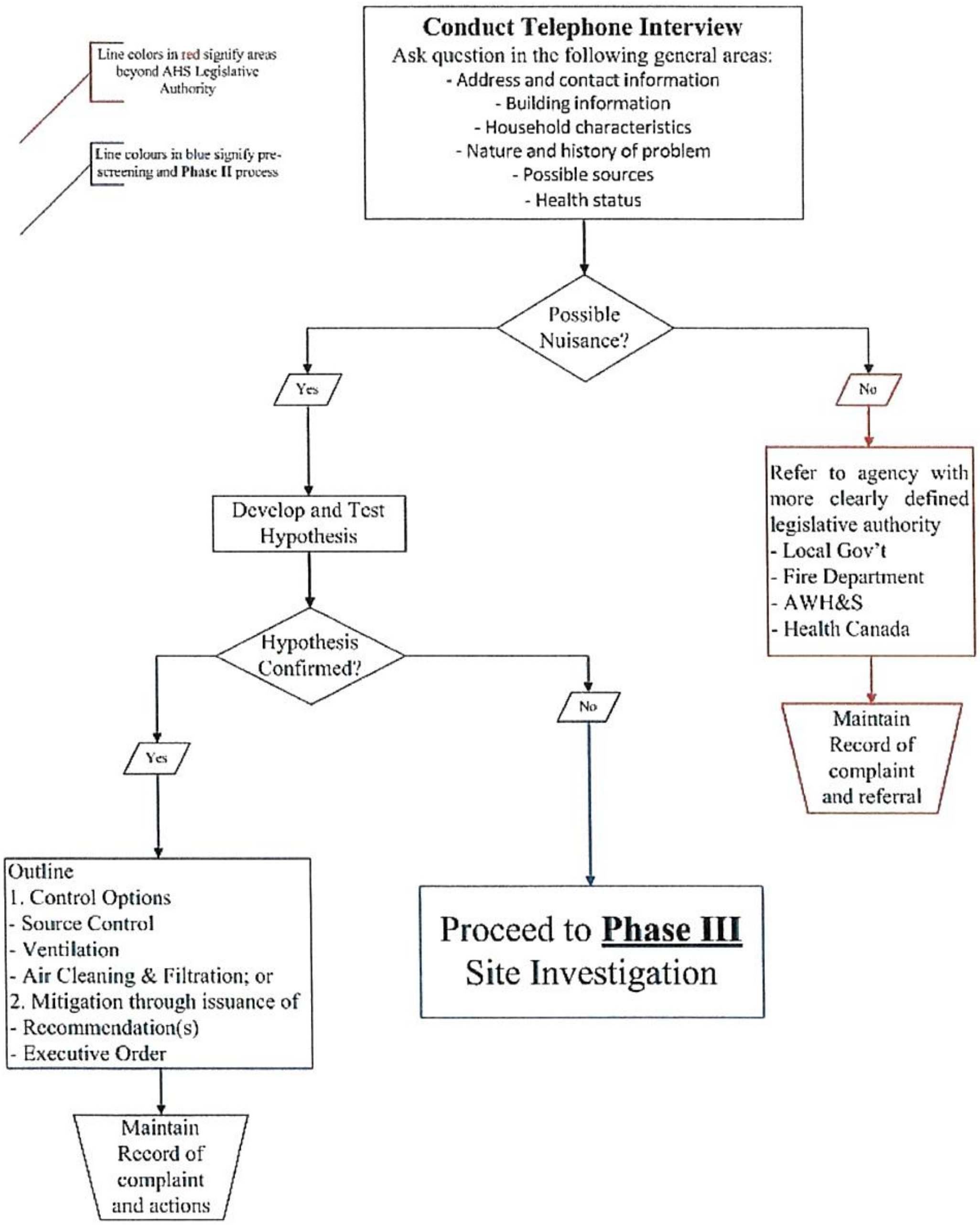
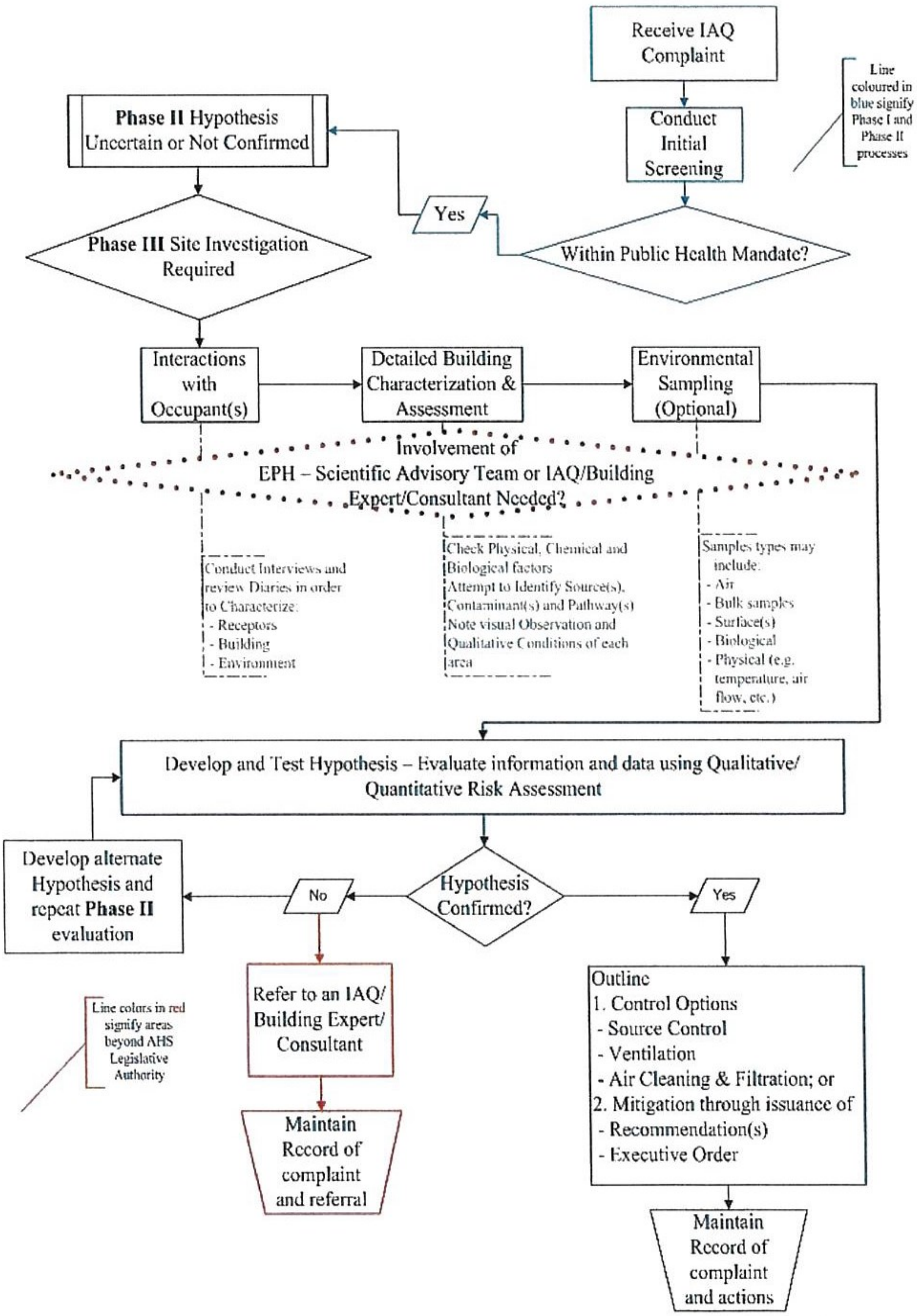


Figure III-B-3: Phase III: IAQ complaint investigation protocol site investigationsc



I.2 IAQ Investigation telephone Interview questionnaire

The purpose of the telephone interview questionnaire is to gather information about the IAQ problem facing the complainant, and about the the building and environment that the complainant is concerned about. The content of this questionnaire is based on ASTM D7297-06- Standard Practice for Evaluating Residential Indoor Air Quality (2006), and AHS-EPH DSOP IAQ - Indoor Air Quality (2012 in development).

Some or all of the questionnaires and questions for interviewing and onsite investigation may be completed based on the assessment and judgment of the investigating public health inspector.

If during the course of the investigation, a hypothesis is developed or source or cause is identified, then the interview can be terminated. If the problem remains following remedial actions, then the interview can resume.

I.2.1 Address and contact information

Questionnaire #:	______________	Date:	____________	Time:	____________ a.m./p.m.
Name of occupant(s):	______________________________				
	______________________________				
Address:	______________________________				
City or town	______________________	Postal code:	______________________		
Home phone #:	______________________	Work phone::	______________________		
Recorder's name	______________________________				

I.2.2 Nature and history of problem

1. Please describe the problem you are experiencing.

____

____

2. When did you first notice the problem?

____

____

____

____

____

____

____

____

3. Is the problem specific to one area of the building? If so, where?

4. Are there any noticeable odours? If so, describe them.

5. Is the problem constant or intermittent?

I.2.3 Health status

1. Please describe any background medical conditions (e.g. asthma, respiratory disease, etc)? Are there any sensitive/vulnerable individuals?

   ____

   ____

2. Who is affected? What symptoms? Onset of symptoms?

   ____

   ____

3. Is anyone in the premise unaffected?

   ____

   ____

4. Has a physician been consulted about the symptoms of the affected individuals?

   ☐ Yes ☐ No

5. If yes, please provide the physician'contact info.

   ____

   ____

I.2.4 Building or facility characteristics

1. Number of users of the building? __________ Number of occupants in the suite? __________

   Provide *the* exact number if possible:

☐ 2 or less ☐ 2 to 5 ☐ 5 to 10 ☐ 10 to 15 ☐ 15 to 20 ☐ 20 or more

2. Ages of occupants

   Provide exact ages if possible:

   ☐ Infants (0 to 6 months), ☐ toddlers (7 months to 4 years),

   ☐ child (5 years to 11 years), ☐ teen (12 – 19 years)

   ☐ adults (20 years to 65 years) ☐ senior (65+ years)

I.2.5 Possible contaminant sources

1. Has the premise been renovated or remodeled?

   ☐ Yes ☐ No

2. If yes, please indicate:

   When? ____

   What was done? ____

Did you notice the problems prior? ______

3. Describe outdoor influences nearby:

______

______

4. Describe indoor activities:

______

______

5. Has any new furniture been introduces to the affected area?

☐ Yes ☐ No,

6. If yes, please indicate:

When? ______

What was introduced? ______

Did you notice the problems prior? ______

7. Has the premise been redecorated?

☐ Yes ☐ No

8. If yes, please indicate:

When? ______

What was done? ______

Did you notice the problems prior? ______

9. Please describe the nature, frequency and duration of any odours and if they coincide with symptoms:

______

______

10. Do signs and symptoms disappear when you leave your premise?

☐ Yes ☐ No

I.2.6 Building information

1. Which of the following best describes the building?
   - ☐ Single-family house (number of bedrooms): ____________
   - ☐ Duplex or row-house (number of bedrooms): ____________
   - ☐ High-rise apartment complex (number of stories): ____________
   - ☐ Low-rise apartment complex (number of stories): ____________
   - ☐ Mobile/modular home or trailer (number of bedrooms): ____________
   - ☐ Office building (number of stories: ____________
   - ☐ Public facility (indicate type of facility) ____________
   - ☐ Institution (indicate type of institution) ____________
   - ☐ Commercial facility (indicate type of facility) ____________
   - ☐ School (indicate primary, junior high, high school, college or university)
   - ☐ a recreational facility (indicate type of facility) ____________
   - ☐ Personal social care facility (indicate type of facility) ____________
   - ☐ Specialized medical facility (indicate type of facility) ____________

2. When was the building constructed?

   Indicate year if known ____________

☐ 2010 or newer	☐ 2009 to 2000	☐ 1999 to 1990
☐ 1989 to 1980	☐ 1979 to 1970	☐ 1969 to 1960
☐ 1959 to 1950	☐ 1949 or older	

3. Is ts Is your home or a rental?
   - ☐ I/ we own and occupy
   - ☐ I/ we rent
   - ☐ Other (specify) ____________

4. How long have you occupied the premise?

   ____

5. Has there been any investigation of the problem?

   ☐ Yes ☐ No

If yes, please indicate:

Conducted by? ______________________

When? ______________________

What was done? ______________________

____

Findings? ______________________

____

6. Please describe the type of major appliances (e.g., gas, electric, etc.)

____

____

7. Please describe the type of heating, ventilation and air conditioning system (e.g. gas/oil furnace, forced air heating, HRV, exhaust vents, etc):

____

____

8. Please describe the physical or thermal comfort factors (relative humidity and temperature):

____

____

I.2.7 Other

1. Any additional comments provided by contact:

____

____

____

As per the investigation process, if the IAQ issue is not resolved at the end of the telephone interview, a site visit is necessary to gather more information for the purposes of resolving the complainants concerns.

If necessary, schedule a site visit:

2. What days of the week and times would be most convenient?

Day

☐ Monday	☐Tuesday	☐ Wednesday	☐ Thursday	☐ Friday

Time

☐ 9am to 10am	☐ 10am to 11am	☐ 11am to noon	☐ 1 pm to 2 pm	☐ 3pm to 4pm

I.3 IAQ Investigation onsite occupant Interview questionnaire

The purpose of the onsite occupant interview questionnaire is to gather more specific information about the IAQ problem. Interaction with the occupant is an important part of the site investigation process. Information from the occupant(s) helps the investigator to further develop the hypotheses. Talk to different occupants, the building manager and owner, if applicable, to gather as much information as possible. Try to interview identified sensitive or vulnerable individuals among building occupants. When talking to different occupants, differentiate them according to their age, sex and health status. These interactions will identify particular areas of concern in the building where emphasis is needed during the building assessment. The content of this questionnaire is based on ASTM D7297-06- *Standard Practice for Evaluating Residential Indoor Air Quality* (2006), and AHS-EPH DSOP IAQ - *Indoor Air Quality* (2012 in development).

I.3.1 Address and contact information

Questionnaire #: Date ______________ Time ______________ a.m./p.m. ______________

Name of interviewee: ______________________________

Facility ype: ______________________________

Associated facility: ______________________________

Address: ______________________________

City/town: ______________ Postal Code: ______________

Recorder's name: ______________________________

I.3.2 Problem information

1. Describe the problem being experienced in your own words:

____

____

____

2. When did you first notice this?

____

3. Can you describe the area of the building where you experience the problem?

____

____

4. Can you think of any possible causes of the problem? (e.g. renos, new furniture, etc.)

____

____

5. Describe any renovations/remodeling at the premise and note approx. when conducted:

6. Who did that work?

☐ Yourself ☐ Other building user ☐ Contractor ☐ Other, specify

7. Have you noticed any other events (such as weather events, temperature or humidity changes, or activities in the building) that tend to occur around the same time as your symptoms?

8. Have you noticed any specific incident or event that can be linked with the initial onset of symptoms (e.g., building renovations, new fans, layout changes, the installation of partitions/dividers, new lighting, furniture, carpeting, roof leaks, dampness in the wall, new paint etc.)?

9. Do you have any observations about building conditions that might need attention or might help explain your symptoms (e.g. temperature, humidity, drafts, stagnant air, odors)

10. Please describe the type of heating, ventilation and air conditioning system (e.g. gas/oil furnace, forced air heating, HRV, exhaust vents, etc):

11. Indicate the location of systems used (if applicable):

Heating:

Cooling:

Filtration:

Humidification:

Exhaust Fans:

12. Have any of the following been replaced, and if so, approximately when?

Furnace	☐Yes, when	________	☐ No
Air conditioning	☐Yes, when	________	☐ No
Ductwork	☐Yes, when	________	☐ No

Water heater	☐Yes, when	______________	☐ No
Range/oven	☐Yes, when	______________	☐ No
Dishwasher	☐Yes, when	______________	☐ No
Clothers washer	☐Yes, when	______________	☐ No
Clothes dryer	☐Yes, when	______________	☐ No
Windows	☐Yes, when	______________	☐ No
Doors	☐Yes, when	______________	☐ No

13. How long have you lived/worked/used this building?

    ____

14. Where do you spend most of your time in the building/suite/room?

15. When do you notice the problem? Is it constant or intermittent? When does it recur?

16. What have you tried to address the problem?

17. Who did that work?

    ☐ Yourself ☐ Other building user ☐ Contractor ☐ Other, specify

18. Have visitors to the premises complained of symptoms?

    ☐ Yes ☐ No

    If yes, please specify:

I.3.3 Potential sources:

1. Are any pets living on the premises?

☐ Yes ☐ No

If yes, please specify:

____

2. Do you smoke?

☐ Yes ☐ No,

If yes, please specify:

Average number of cigarettes/cigars smoked ______________

Is there a designated smoking area? ______________

Where? ______________

Indoors or outdoors? ______________

Do others smoke? ______________

3. Do you use any of the following indoors and how often?

Candles	☐ Yes, frequency ______	☐ No
Oil lamps	☐ Yes, frequency ______	☐ No
Printers	☐ Yes, frequency ______	☐ No
Copiers	☐ Yes, frequency ______	☐ No
Hair spray	☐ Yes, frequency ______	☐ No
Oven cleaner	☐ Yes, frequency ______	☐ No

4. Do you start your car in the garage?

☐ Yes, ☐ No

If yes describe frequency of occurrences and duration of idling in the garage:

____

5. Have you experienced any flooding or water damage associated with any of the following and approx. when?

Burst pipes	☐ Yes, when ________	☐ No
Type :	☐ Sewerage	☐ Potable water
Flooding	☐ Yes, when ________	☐ No
Type:	☐ surface water flow	☐ groundwater rise
Roof leaks	☐ Yes, when ________	☐ No

6. Have you experienced any condensation or rain/snow penetration or leakage at any of the following and approx. when?

Windows	☐ Yes, when ________	☐ No
Doors	☐ Yes, when ________	☐ No

7. In response to answers of "yes" to questions 5 and 6 what was done (remedial action(s)) and how much time elapsed between the "event" and the remedial action?

____

____

8. Do you use a humidifier and how often?

☐ Yes ☐ No

9. If yes, describe use frequency and the kind of humidifier?

____

10. Describe how the humidifier is maintained (cleaned and sanitized?) and the frequency of maintenance:

____

____

11. Do you use any of the following for supplemental heat and how often?

Fireplace?

☐ Wood ☐ Yes, frequency _______ ☐ No

☐ Gas ☐ Yes, frequency _______ ☐ No

Woodstove?

☐ Yes, frequency _______ ☐ No

Space heater?

☐ Kerosene ☐ Yes, frequency _______ ☐ No

☐ Unvented ☐ Yes, frequency _______ ☐ No

☐ Electric ☐ Yes, frequency _______ ☐ No

12. If you use any of the above, do you notice a smell from them?

Fireplace?

☐ Wood ☐ Yes, frequency _______ ☐ No

☐ Gas ☐ Yes, frequency _______ ☐ No

Woodstove?

☐ Yes, frequency _______ ☐ No

Space heater?

☐ Kerosene ☐ Yes, frequency _______ ☐ No

☐ Unvented ☐ Yes, frequency _______ ☐ No

☐ Electric ☐ Yes, frequency _______ ☐ No

13. Do you notice drafts at any of the following and how often?

Doors ☐ Yes, frequency _______ ☐ No

Windows ☐ Yes, frequency _______ ☐ No

Wall outlets ☐ Yes, frequency _______ ☐ No

Exhaust vents ☐ Yes, frequency _______ ☐ No

14. Do you notice condensation on any of the following in winter?

Doors ☐ Yes ☐ No

Windows ☐ Yes ☐ No

If yes describe frequency and where:

____

15. Are windows and doors kept mostly: ☐ open ☐ closed

16. What cleaning products are used and where are they kept?

____

____

17. What pesticides and fertilizers are used and where are they kept?

____

____

18. Have any new furnishings been brought into the building?

☐ Yes ☐ No

If yes, describe when and what furnishings:

____

____

19. Has there been any painting recently?

☐ Yes ☐ No

If yes, what kind of paint? ☐ Oil ☐ Latex ☐ Low VOC

Describe when and where:

____

____

20. Are any of the following activities completed indoors?

Woodworking	☐ Yes, frequency ___________	☐ No
Photo processing	☐ Yes, frequency ___________	☐ No
Artwork	☐ Yes, frequency ___________	☐ No
Floral care & arrangement	☐ Yes, frequency ___________	☐ No
Growing & plant care	☐ Yes, frequency ___________	☐ No
Other chemical use	☐ Yes, frequency ___________	☐ No

Specify chemicals used:

I.3.4 Health status

1. Please describe any background medical conditions (e.g. asthma, respiratory disease, etc)? Are you sensitive/vulnerable to anything specific?

____

____

____

____

2. What symptoms? Onset of symptoms?

____

____

____

3. Have you consulted a physician about your symptoms?

   ☐ Yes ☐ No

4. If yes, please explain what the doctor said and provide the contact info.

____

____

5. Did the doctor give you any medication? Please specify:

____

How old are you? ____________________

I.3.5 Symptom Info

1. Where are you when you experience health concerns or discomfort?

____

____

2. Where do you experience these health concerns?

   ☐ only at home ☐ at home and work ☐ all the time

   Do the symptoms become less severe when away from the premises for a period of time?

   ☐ Yes ☐ No

   If yes, please describe any changes:

____

____

3. When do they generally start in the day?

   ☐ mornings ☐ afternoons ☐ all day long

   ☐ no noticeable patterns

4. When are they generally worst? (e.g. spring summer autumn winter)

____

____

5. Has the symptom severity increased?

	Yes	No	Don't know	N/A
During warm, humid weather	☐	☐	☐	☐
During rainy weather	☐	☐	☐	☐
During the air conditioning season	☐	☐	☐	☐
At the beginning of the heating season	☐	☐	☐	☐
Is the symptom severity decreased?	Yes	No	Don't know	N/A
When the humidifier is used	☐	☐	☐	☐
On very cold days	☐	☐	☐	☐
When windows are open	☐	☐	☐	☐

I.3.6 Information on occupation

1. Complainant's occupation:

____

2. Relevant information and work activities (e.g., is your job stressful, work related disease, or work with VDTs (video display terminals?), solvents, etc.)

____

____

____

3. How would the complainant classify their occupation?

☐ highly stressful ☐ moderately stressful ☐ low stress

4. What type of work do you do?

☐ volunteer ☐ part time ☐ full time

5. Work and Exposure history (if any)

Company Name and Work Location	From (mm/year)	To (mm/year)	Job title and description	Exposures[1]	PPE/Protective measure[2]
1					
2					
3					

[1]List significant chemicals, dusts, fibres, radiation, biologic agents, (bacteria, mould, etc.) and physical agents (heat, cold, noise, vibration, etc.) that you were exposed

[2]List protective measures taken in order to avoid exposure.

I.3.7 Other

Any additional comments provided by the contact:

I.4 IAQ Investigation onsite walk-through questionnaire

The onsite walk-through investigation may not be necessary if during the previous investigation steps, a source or cause has been confirmed and corrective actions have rectified the problem.

The purpose of the onsite walk-through survey is to identify and assess different sources of contaminants and their pathways. Identify different factors including physical, chemical and biological that may be responsible for health symptoms reported by different occupants. Perform a thorough walk-through survey of different parts of the building and—the building HVAC system if necessary. The content of this questionnaire is based on ASTM D7297-06- *Standard Practice for Evaluating Residential Indoor Air Quality* (2006), and AHS-EPH DSOP IAQ - *Indoor Air Quality* (2012 in development).

Some or all of the questionnaires and questions for interviewing and onsite investigation may be completed based on the assessment and judgment of the investigating Health Inspector. If during the course of the investigation, a source or cause is identified or hypothesis developed, then further work is not needed.If the hypothesis is not confirmed; that is, corrective measures were taken but the problem remains, investigation and use of the questionnaire may continue.

Some or all of the questionnaires and questions for interviewing and onsite investigation may be completed based on the assessment and judgment of the investigating public health inspector.

If during the course of the investigation, a source or cause is identified or hypothesis developed, then further work is not needed. If the hypothesis is not confirmed, ie corrective measures are taken but the problem remains, investigation and use of the questionnaire may continue.

Note: use a separate form for each person interviewed.

I.4.1 Address and contact information

Questionnaire #: ____________ Date: ____________ Time: a.m./p.m. ____________

Name of interviewee: ______________________________

Facility type: ______________________________

Associated facility: ______________________________

Address: ______________________________

City/town: ____________________ Postal Code: ____________________

Recorder's name ______________________________

I.4.2 General

1. When was the building constructed? Year built: __________ Approximate age: __________

2. Which of the following best describes the building?

   ☐ Slab on grade ☐ Full basement ☐ Finished ☐ Unfinished

☐ Foundation type ☐Concrete ☐Preserved wood

3. Floor type

   ☐ Earthen floor ☐ Earth floor without vapour barrier

   ☐ Earth floor without vapour barrier ☐ Concrete ☐ Preserved wood

   ☐ Crawlspace ☐ Concrete floor

4. Construction material (e.g., brick, wood frame, concrete, cinder blocks, etc.):

   ____

   ____

5. Thermal insulation type? (e.g., sprayed, foam, fiberglass, etc.)

   ____

   ____

6. Location(s)? (e.g., walls, attic, floors, etc.)

   ____

   ____

7. Number of users of the building?

   Provide exact number if possible: ____________________

   ☐ 2 or less ☐ 2 to 5 ☐ 5 to 10 ☐ 10 to 15 ☐ 15 to 20 ☐ plus 20

   Designed occupancy limit (if specified): ____________________________

8. Number of floors (count attic or basement if it has any finished rooms): ________

9. Square footage/floor: __________ Total square footage: __________

   Ages of occupants

   Provide exact ages if possible: ________________________

   ☐ Infant (0 to 6 months) ☐ Toddlers (7 months to 4 years)

   ☐ Child (5 years to 11 years) ☐ Teen (12 – 19 years)

   ☐ Adults (20 years to 65 years) ☐ Senior (65+ years)

10. Does the building have a garage?

    ☐ Yes ☐ No

If yes, ☐ Attached ☐ Detached ☐ Carport ☐ Parkade ☐ Surface parking

11. Do any occupants smoke?

    ☐ Yes ☐ No ☐ Don't know

12. Pets in residence?

    ☐ Yes ☐ No ☐ Don't know

I.4.3 Exterior walk-through

Complete schematic of exterior of building noting all areas of concern

1. Neighbourhood:

   ☐ Rural ☐ Commercial ☐ Industrial ☐ Urban ☐ Agricultural

2. Describe outdoor influences nearby:

   ____

   ____

3. Heavy traffic: ☐ Yes ☐ No ☐ Don't know

4. Describe the traffic situation:

   ____

   ____

5. Traffic density near premise:

   ☐ High ☐ Moderate ☐ Low

   Vehicle idling area: ☐ Yes ☐ No ☐ Don't know

   Dump site: ☐ Yes ☐ No ☐ Don't know

   Farms(s): ☐ Yes ☐ No ☐ Don't know

   Industrial plant(s): ☐ Yes ☐ No ☐ Don't know

   Radiation source: ☐ Yes ☐ No ☐ Don't know

   Polluted lake/stream: ☐ Yes ☐ No ☐ Don't know

   Other hazards: ☐ Yes ☐ No ☐ Don't know

   Specify: ______________________________________

6. Possible contaminant source located near building fresh air intake(s)

   ☐ Yes ☐ No

   If yes, specify type of source: ____________________________

   Specify approx. distance and direction: ____________________________

7. Use of pesticides or fertilizers: ☐ Yes ☐ No ☐ Don't know

   If yes, specify type(s):

   ____

   Specify location(s) used:

   ____

   ____

Construction and condition

1. Chimneys/flues:

   Number: ______

   Type/construction material:

   ____

   ____

   Location(s):

   ____

   ____

   Potential for water penetration:

   ____

   ____

2. Roof:

   ☐ Flat ☐ Sloped, specify approximate slope: ______________

   Type/construction material:

   ____

   ____

   Condition:

   ____

   ____

   Potential for water penetration:

   ____

   ____

3. Gutters/downspouts:

   Condition: _______________________ Splashblocks: ________________

   Blockages: ☐ Yes ☐ No ☐ Don't know

   ☐ Directed away from house

   ☐ Connected to weeping tile/below grade

4. Drainage:

   Ground graded/slopes away from building ☐ Yes ☐ Not

   If yes, specify approx. slope: _________________________

   Ground condition: ☐ Wet ☐ Spongy ☐ Solid/dry ☐ Standing water

   Note potential for water accumulation:

   ____

   ____

5. Exterior condition:

Locations of vest (mechanical, plumbing, appliance, etc.)

____

Staining

____

Locations of construction flaws/repairs

____

Siding/sheathing

____

Cracks/gaps/penetrations, specify location(s)

____

I.4.4 Interior walk-through

Complete schematic of each interior floor of building noting all areas of concern

I.4.4.1 Problem Description

1. Is the problem specific to one area of the building? If so, where?

   ____

   ____

2. Are there any noticeable odours? If so, describe them.

   ____

   ____

3. Please describe the physical or thermal comfort factors (relative humidity and temperature):

   ____

   ____

4. Describe if there appears to be a connection from the garage into the building (i.e. air flows from garage into building)?

   ____

   ____

   ____

5. Describe any evidence of (note locations, remedial actions, response time and type of water or pipe involved):

   Burst pipes:

   ____

   Floods:

   ____

   Roof leaks:

   ____

   Leaks/condensation at windows (air/drafts or water):

   ____

   Leaks/condensation at doors (air/drafts or water):

   ____

I.4.5 HVAC systems

1. Please describe the type of heating, ventilation and air conditioning system (e.g. gas/oil furnace, forced air heating, HRV, exhaust vents, etc):

____

____

2. Indicate the location of systems used, if applicable.

   Heating:

   ____

   Cooling:

   ____

   Filtration:

   ____

   Humidification:

   ____

   Exhaust Fans:

   ____

3. Approx. age of systems used (if applicable):

   Heating:

   ____

   Cooling:

   ____

   Filtration:

   ____

   Humidification:

   ____

   Exhaust Fans:

   ____

4. Indicate the frequency of cleaning for each system (e.g., monthly, yearly, etc.). Inspect to assess the cleanliness of each system:

   Heating system: ________________ ☐ Clean ☐ Dirty

   Cooling system: ________________ ☐ Clean ☐ Dirty

   Filtration system: ________________ ☐ Clean ☐ Dirty

   Humidification system: ________________ ☐ Clean ☐ Dirty

   Exhaust fans: ________________ ☐ Clean ☐ Dirty

   What is the main type of fuel used to heat the building?

   ☐ Gas ☐ Wood ☐ Electricity ☐ Fuel oil ☐ Kerosene

   ☐ Other, specify: ________________

5. Does the building have a heat recovery ventilator (HRV)?

☐ Yes ☐ No,

If yes, please describe the HRV.

____

6. Systems condition (inspect to assess condition):

☐ Filters ☐ Clean ☐ Dirty

☐ Ducting ☐ Clean ☐ Dirty

7. Supplemental heating sources:

☐ Fireplace ☐ Wood ☐ Gas ☐ Wood burning stove

☐ Unvented gas or kerosene space heater

☐ Other, specify: ____

8. Air conditioning system:

☐ Central air ☐ Window unit

☐ Humidifier ☐ Through-wall unit

Alterations to the system? ☐ Yes ☐ No ☐ Don't Know

If yes, please describe the system and any alterations:

____

____

____

I.4.5.1 Alterations to the building

1. Describe any evidence of major renovations or operating changes to the building:

____

____

____

2. Describe any evidence of improvement to the degree of thermal insulation in the building in the recent past? (Include the addition or replacement of roof insulation, wall insulation, storm windows or doors, or double-glazing.)

   ☐ Yes ☐ No ☐ Don't know

3. Type and year of improvement:

____

____

____

4. Describe any evidence of new carpets, furniture, or cabinets recently been installed?

   ☐ Yes ☐ No ☐ Don't know

If yes, please specify what, and when:

____

____

5. Conditions of fixtures

   Plumbing fixtures – sinks, faucets, drains, pipes

Kitchen:	☐ Leaks	☐ Water stains	
Bathroom:	☐ Leaks	☐ Water stains	
Toilet:	☐ Good repair	☐ Water stains	☐ Leaks
Shower/bathtub:	☐ Good repair	☐ Water stains	☐ Leaks
Laundry:	☐ Good repair	☐ Water stains	☐ Leaks

   ☐ Other, specify: ______________________________

6. Living areas

   General: ☐ Temperature/RH ☐ Odours ☐ Vermin

   Describe any problem:

____

____

7. Sanitation: ☐ Sanitary ☐ Unsanitary

   Describe the situation.:

____

____

8. Finishes:

   Walls/ceilings

   ☐ Good condition ☐ Stained/soiled ☐ Mould

☐ Flaking paints ☐ Recent renovations/painting

9. Flooring

☐ Good condition ☐ Stained/soiled ☐ Mould

☐ Water stains ☐ Wet/damp ☐ Recent renovations/painting

10. Area carpets

☐ Good condition ☐ Stained/soiled ☐ Mould

☐ Water stains ☐ Wet/damp ☐ Other, specify: ____________

Windows/Doors: ☐ Insect screens ☐ General condition/operable

11. Furnishings - upholstered furniture

☐ Sofa ☐ Chairs ☐ Other,
specify:________________________

☐ New ☐ Good condition ☐ Stained/soiled

12. Sleeping arrangements

☐ Mattress with box spring:

☐ Good condition ☐ Elevated off floor ☐ Mattress cover

☐ Mattress without box spring:

☐ Good condition ☐ Elevated off floor ☐ Mattress cover

☐ other, specify: ____

Bedding/Linen: ☐ Clean ☐ Soiled

Stuffed toys: ☐ Clean ☐ Soiled

13. Basement

Condition of foundation walls: ☐ Staining ☐ Efflorescence/white crystals

Gaps at penetrations in: ☐ Slab ☐ Walls

Note possible areas/points for soil gas and/or water intrusion:

____

____

14. Appliances

Cooking:

☐ Gas Stove ☐ Electric Stove ☐ Vented ☐ Clean ☐ Dirty

Laundry

Washer: ☐ Properly drains ☐ Standing water ☐ Leaks

Dryer: ☐ Vented to outside ☐ Dryer lint visible

Cleaning

Dishwasher: ☐ Properly drains ☐ Standing water ☐ Leaks

Vacuum: ☐ Central ☐ Portable ☐ HEPA filter ☐ Bagless

15. Water heater fuel:

☐ Gas ☐ Electric ☐ Vented ☐ Clean ☐ Dirty

Approx. age of water heater: __________ ☐ Rust colour stains on exhaust ducts

16. Activities/uses

Indicate any processes or activities in the building that may serve as contaminant sources:

____

____

Please describe the type of major appliances (e.g., gas, electric, etc.)

____

____

17. What type of fuel is used for cooking?

☐ Gas ☐ Electricity ☐ Fuel oil

☐ Other, specify: _______________________

18. Consumer products used in premise:

☐ Chemicals ☐ Paints ☐ Cleaners ☐ Pesticides

☐ Adhesives ☐ Cosmetics ☐ Air fresheners

☐ Other, specify: _______________________

19. Appropriate storage

☐ Yes ☐ No ☐ Don't know

Please describe any storage concerns:

____

____

I.4.6 Investigation/remediation/mitigation

1. Has there been any investigation of the problem?

   ☐ Yes ☐ No

   If yes, please indicate:

   Conducted by? ______________________________

   When? ______________________________

   What was done? ______________________________

   ____

   What were the findings? ______________________________

   ____

2. How have you tried to address the problem?

   ____

   ____

3. Who did that work?

   ☐ Building owner ☐ Building user ☐ Contractor

   ☐ other, specify ______________________

Other

4. Any additional comments:

   ____

   ____

   ____

   ____

   ____

   ____

   ____

Schematic Diagram – Exterior

Indicate North

Front of Property

Floor:

This template will allow you to sketch ot the floor plan of the location of concerns. Copy page as necessary to accommodate each floor of theinvestigation.

Schematic Diagram – Exterior

Indicate North

Front of Property

Floor: _____

This template will allow you to sketch or the floor plan of the location of concerns. Copy page as necessary to accommodate each floor of premise/area under investigation.

Appendix U:

Government of Alberta, August 2009, Employment and Immigration, Indoor Air Quality Toolkit, Sample Health Survey

Health Survey - Confidential

Name:	Department/Position:
Survey Date:	Interviewer (if applicable):
Work Location / Building Area	

Background Information:

How long have you been working for your employer? _______ Yrs.

Where do you spend most of your time at work?

Have there been any changes in the office recently? E.g.: new location, renovation, cleaning

Symptoms & Patterns:

Check all the symptoms or discomfort you are experiencing:

- ❑ Headache
- ❑ Nausea
- ❑ Dizziness
- ❑ Tiredness / fatigue
- ❑ Irritation of eyes, nose, throat
- ❑ Breathing Problems
- ❑ Coughing
- ❑ Sneezing
- ❑ Wheezing
- ❑ Shortness of Breath
- ❑ Blurred Vision
- ❑ Sinus Congestion
- ❑ Difficulty in concentrating
- ❑ Pain and discomfort of:
  - ❑ Back
  - ❑ Neck
  - ❑ Hands
  - ❑ Wrist
  - ❑ Shoulders
- ❑ Other ____________________

Do you have any other health conditions that may make symptoms worse?

E.g.: allergies, immune system disorders, or chronic cardiovascular or respiratory disease

Health Survey - Confidential

(page 2 of 3)

Have you seen a doctor for these symptoms? 1 Yes 1 No

(Do you wish to provide general details?)

Timing:

When do you notice these symptoms and how often do they occur?

On average, when you notice the symptoms, how long have you been at work?

1 Less than 1 hour 1 2-4 hours 1 > 4 hours 1 1 day 1 After __ days

Has there been any change to the symptoms or patterns? 1 Yes 1 No

If yes, please explain:

When do the symptoms go away? 1 Overnight 1 After a week away 1 Rarely/Never

Can you provide more information?

Has the pain or discomfort caused you to take time off work? 1 Yes 1 No

Are you aware of other people with similar symptoms or concerns? 1 Yes 1 No

If yes, can you provide more details?

Suspected or Potential Causes:

Check any of the following that are true:

- ❑ Are there any unusual odours?
- ❑ Does the air seem stuffy?
- ❑ Is the air dry?
- ❑ Is it dusty?
- ❑ Do you get shocks from static electricity?
- ❑ Is the work area too warm?
- ❑ Is the work area too cool?
- ❑ Does the temperature vary from room to room?
- ❑ Are there drafts where you work?

Health Survey - Confidential

Do you think any of the following might be causing problems at your workstation?

- ❑ Air circulation
- ❑ Humidity
- ❑ Dryness
- ❑ Air conditioning
- ❑ Temperature
- ❑ Noise
- ❑ Lighting / glare
- ❑ Odours
- ❑ Air contaminants
- ❑ Machinery or equipment
- ❑ Cigarette smoke
- ❑ Overcrowding
- ❑ Dividers or wall partitions
- ❑ Dusts and particles
- ❑ Pesticide spraying
- ❑ New furnishings / carpet
- ❑ Other ____________________
- ❑ I don't know

Have you noticed other events (weather, temperature, humidity, or activities in the building) that occur around the same time as your symptoms?

Have there been any changes in the work environment? E.g.: duties, equipment, products

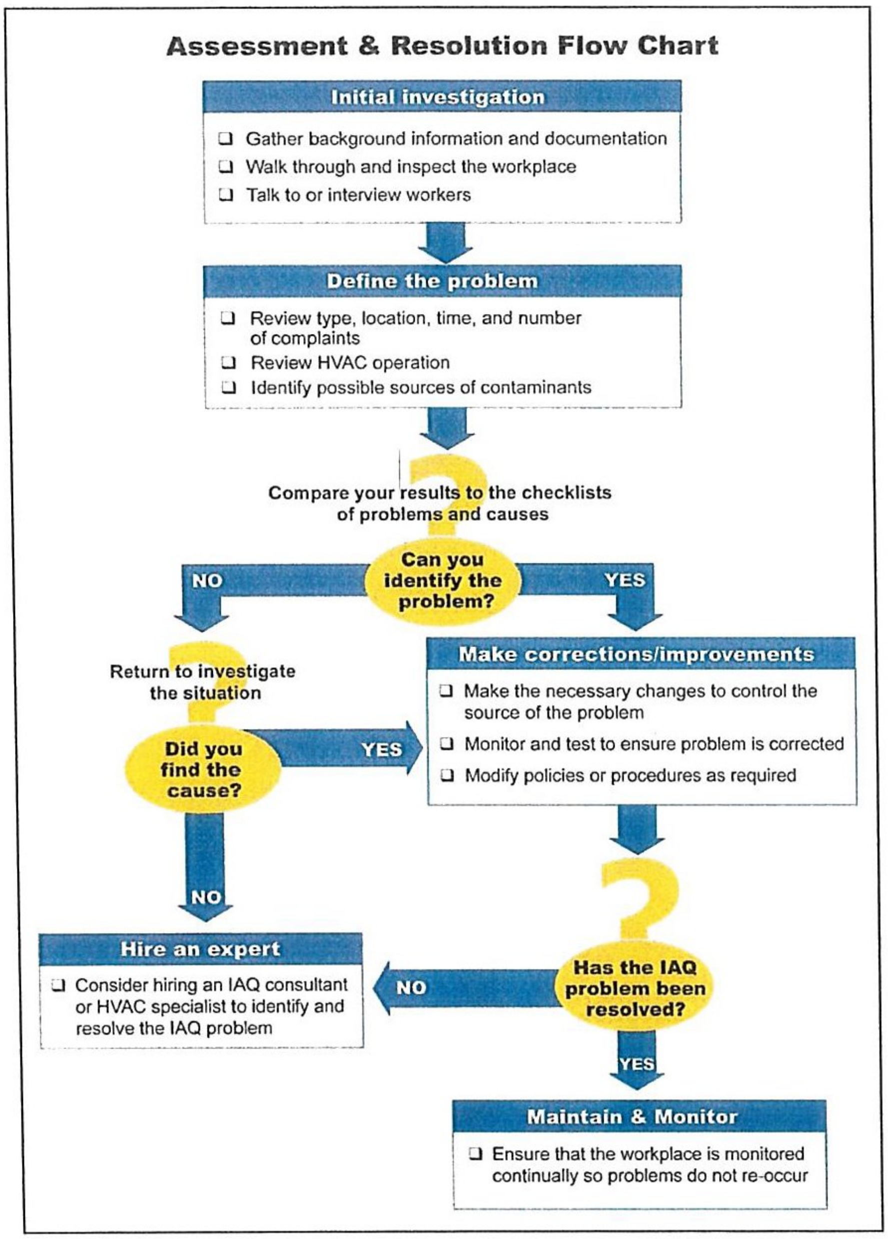
Additional Information:

Please provide any comments or suggestions on how to improve the air quality in the workplace.

Appendix V:

Government of Alberta, August 2009, Employment and Immigration, Indoor Air Quality Toolkit, Assessment and Resolution Flow Chart

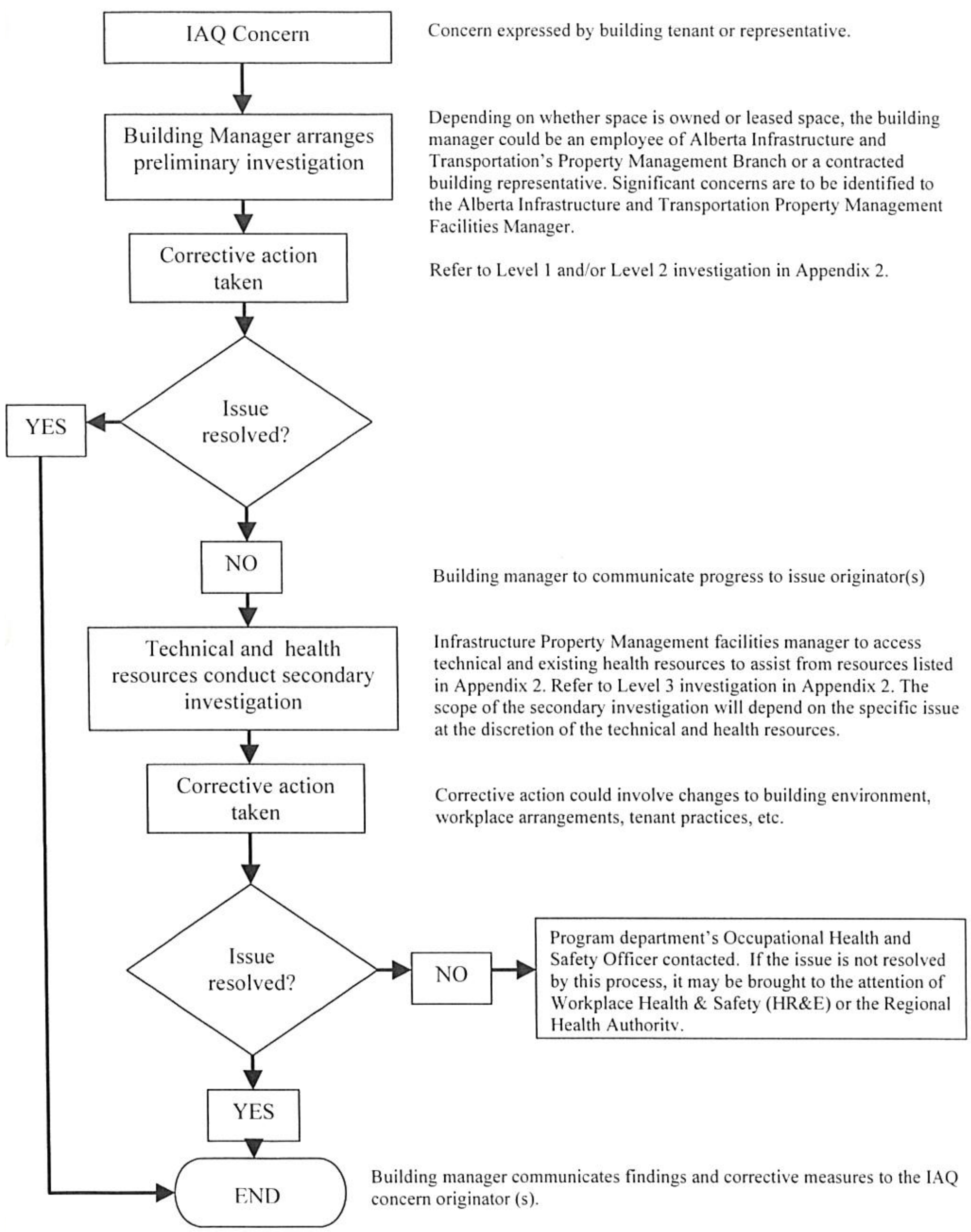
Refer to the following Assessment & Resolution flow chart as a guide.



Appendix W:

Government of Alberta, June 2006 (Revised June 2007), Alberta Infrastructure, Appendix 1:

IAQ Response Process and Walk-Through Checklist



IAQ Walk-Through Checklist

Location: Department:

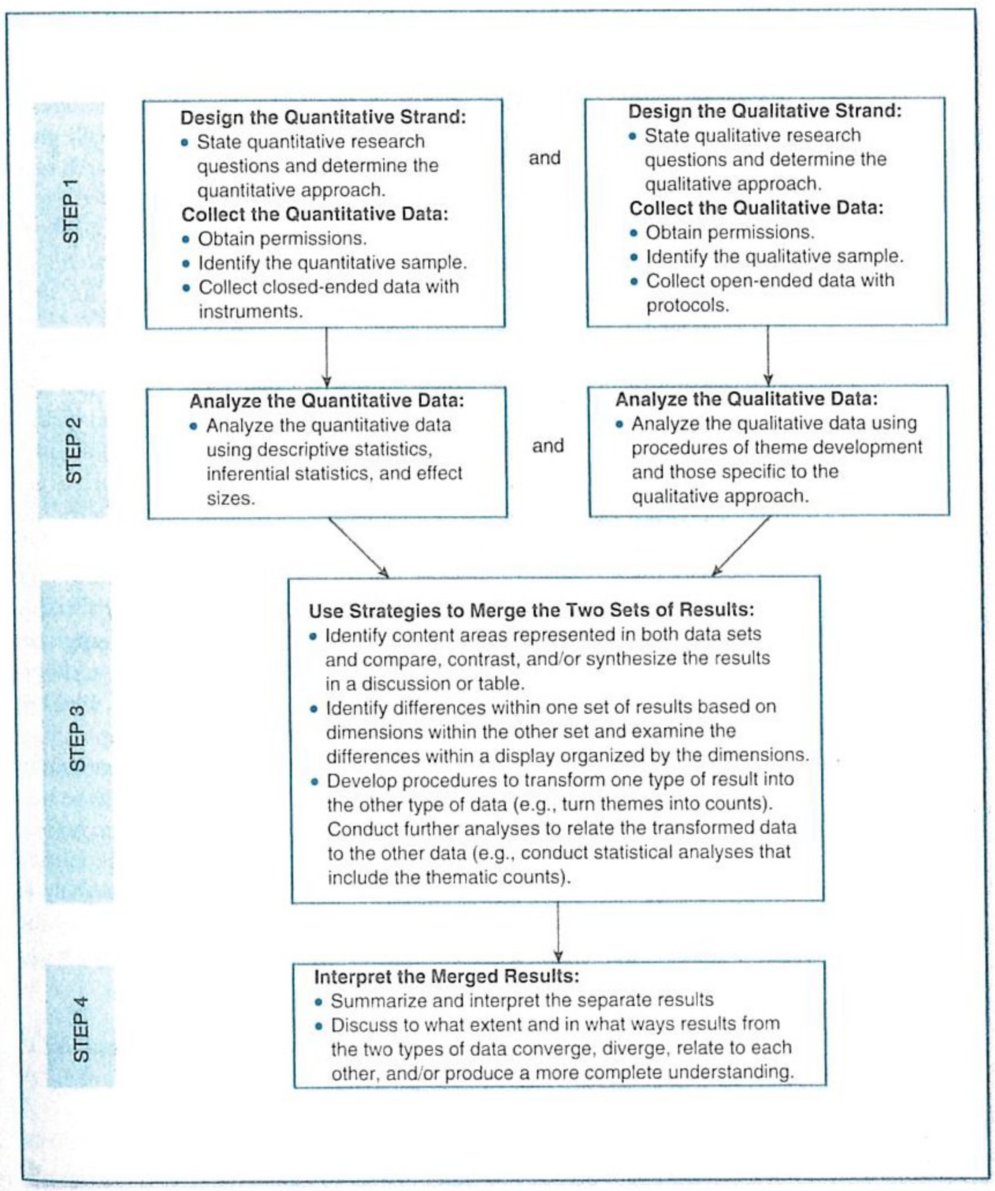
Completed By: Date:

Item	Y/N	Comments
Occupied Spaces		
Concerns/symptoms from occupants.		
Are there complaints of too hot or too cold?		
Are occupants using portable fans, heater, humidifiers?		
Any noticeable odours?		
Is it stuffy?		
Any obstructions (partitions, screens) blocking ventilation grills, thermostats?		
Any signs of inadequate cleaning?		
Is there any air movement through the supply diffusers?		
Are there dust marks around ceiling diffusers or return air grills?		
Does glare appear to be a problem?		
Any cleaning chemicals? Pesticides/herbicides for indoor plants?		
Any office equipment that may require special ventilation?		
Are there any visible signs of water leakage or condensation?		
Ventilation System		
Air intake locations close to potential contaminant sources, e.g. building, washroom, boiler exhausts, loading dock?		
Humidification system? Drain pans clean?		
Filters in the ventilation system?		
Carbon Monoxide – Combustion Products		
Does the building contain an internal parking garage?		
Does the building contain an internal loading dock?		
Does the building contain a gas-fired heating system?		

Appendix X:

Creswell, J. W. and Clark, V.L.P., 2011, Flowchart of the Basic Procedures in Implementing Convergent Design, Figure 3.3

Figure 3.3 Flowchart of the Basic Procedures in Implementing a Convergent Design



Appendix Y:

Government of Canada, 2013, Canadian Centre for Occupational Health and Safety, OSH Answers Fact Sheets, Carbon Monoxide

CCOHS Canadian Centre for Occupational Health and Safety (http://www.ccohs.ca/)

Home / OSH Answers / Chemical Profiles

OSH Answers Fact Sheets

Easy-to-read, question-and-answer fact sheets covering a wide range of workplace health and safety topics, from hazards to diseases to ergonomics to workplace promotion. MORE ABOUT (../../about.html) >

Search all fact sheets:

SEARCH

Type a word, a phrase, or ask a question

HELP (http://www.ccohs.ca/help/

Carbon Monoxide

OPEN ALL | CLOSE

▼

What are other names or identifying information for carbon monoxide?

CAS Registry No.: 630-08-0
Other Names: CO
Main Uses: Manufacture of other chemicals, metallurgy, calibration gas.
Appearance: Colourless gas.
Odour: Odourless

Canadian TDG: UN1016

▼

What is the WHMIS 1988 Classification?

A - Compressed Gas; B1 - Flammable Gas; D1A - Very Toxic; D2A - Very Toxic (Teratogenicity/embryotoxicity)

Class A

Class B1

Class D1A

Class D2A

▼

What are the most important things to know about carbon monoxide in an emergency?

Emergency Overview: Colourless gas. Odourless. EXTREMELY FLAMMABLE GAS. Distant ignition and flashback are possible. COMPRESSED GAS. Contains gas under pressure. May explode if heated. VERY TOXIC. Fatal if inhaled. Causes damage to blood. TERATOGEN/EMBRYOTOXIN. May damage the unborn child. May cause frostbite.

▼

What are the potential health effects of carbon monoxide?

Main Routes of Exposure: Inhalation.

- **Inhalation:** VERY TOXIC. Can harm the blood (decreased ability to carry oxygen). Symptoms may include headache, nausea, dizziness, drowsine and confusion. May cause permanent damage to organs including the brain and heart.
- **Skin Contact:** Not irritating. Direct contact with the liquefied gas can chill or freeze the skin (frostbite). Symptoms of mild frostbite include numbnes prickling and itching. Symptoms of more severe frostbite include a burning sensation and stiffness. The skin may become waxy white or yellow. Blistering, tissue death and infection may develop in severe cases.
- **Eye Contact:** Not irritating. Direct contact with the liquefied gas can freeze the eye. Permanent eye damage or blindness can result.
- **Ingestion:** Not a relevant route of exposure (gas).
- **Effects of Long-Term (Chronic) Exposure:** Conclusions cannot be drawn from the limited studies available. May harm the nervous system. May harm the heart.
- **Carcinogenicity:** Not a carcinogen.

International Agency for Research on Cancer (IARC): Not specifically evaluated.
American Conference for Governmental Industrial Hygienists (ACGIH): Not specifically designated.

- **Teratogenicity / Embryotoxicity:** DEVELOPMENTAL HAZARD. May harm the unborn child. Has been associated with: low birth weight or size, learning disabilities, miscarriage.
- **Reproductive Toxicity:** Not known to be a reproductive hazard.
- **Mutagenicity:** Not known to be a mutagen. Conclusions cannot be drawn from the limited studies available.

▼

What are first aid measures for carbon monoxide?

Inhalation: Take precautions to prevent a fire (e.g. remove sources of ignition). Take precautions to ensure your own safety before attempting rescue (e. wear appropriate protective equipment). Move victim to fresh air. If breathing is difficult, trained personnel should administer emergency oxygen. If the he has stopped, trained personnel should start cardiopulmonary resuscitation (CPR) or automated external defibrillation (AED). Immediately call a Poison Centre or doctor. Treatment is urgently required. Transport to a hospital.

Skin Contact: Not applicable (gas). Liquefied gas: quickly remove victim from source of contamination. DO NOT attempt to rewarm the affected area on site. DO NOT rub area or apply direct heat. Gently remove clothing or jewelry that may restrict circulation. Carefully cut around clothing that sticks to the skin and remove the rest of the garment. Loosely cover the affected area with a sterile dressing. DO NOT allow victim to drink alcohol or smoke. Immediately call a Poison Centre or doctor. Treatment is urgently required. Transport to a hospital.

Eye Contact: Not applicable (gas). Liquefied gas: immediately and briefly flush with lukewarm, gently flowing water. DO NOT attempt to rewarm. Cover both eyes with a sterile dressing. DO NOT allow victim to drink alcohol or smoke. Immediately call a Poison Centre or doctor. Treatment is urgently required. Transport to a hospital.

Ingestion: Not applicable (gas).

First Aid Comments: Some of the first aid procedures recommended here require advanced first aid training. All first aid procedures should be periodica reviewed by a doctor familiar with the chemical and its conditions of use in the workplace.

▼

What are fire hazards and extinguishing media for carbon monoxide?

Flammable Properties: EXTREMELY FLAMMABLE GAS. Can easily ignite. Can readily form explosive mixture with air at room temperature.

Suitable Extinguishing Media: Carbon dioxide, dry chemical powder, appropriate foam, water spray or fog. Foam manufacturers should be consulted fo recommendations regarding types of foams and application rates.

Specific Hazards Arising from the Chemical: Gas or vapour may accumulate in hazardous amounts in low-lying areas especially inside confined space resulting in a health hazard. Heat from fire can cause a rapid build-up of pressure inside cylinders. Explosive rupture and a sudden release of large amounts of gas may result. Cylinder may rocket. In a fire, the following hazardous materials may be generated: Very toxic carbon monoxide, carbon dioxide.

▼

What are the stability and reactivity hazards of carbon monoxide?

- **Chemical Stability:** Normally stable.
- **Conditions to Avoid:** Open flames, sparks, static discharge, heat and other ignition sources.
- **Incompatible Materials:** Increased risk of fire and explosion on contact with: oxidizing agents (e.g. peroxides), halogens (e.g. chlorine), metals (e.g aluminum). Not corrosive to: aluminum alloys, stainless steel.
- **Hazardous Decomposition Products:** At high temperatures: carbon and carbon dioxide.
- **Possibility of Hazardous Reactions:** None known.

▼

What are accidental release measures for carbon monoxide?

Personal Precautions: Evacuate the area immediately. Isolate the hazard area. Keep out unnecessary and unprotected personnel. Use personal protective equipment as required. Eliminate all ignition sources. Use grounded, explosion-proof equipment. Vapour or gas may accumulate in hazardous amounts in low-lying areas especially inside confined spaces, if ventilation is not sufficient.

Methods for Containment and Clean-up: Ventilate the area to prevent the gas from accumulating, especially in confined spaces. Stop or reduce leak if safe to do so. Knock down gas with fog or fine water spray. Dike and recover contaminated water for appropriate disposal.

▼

What handling and storage practices should be used when working with carbon monoxid

Handling: Before handling, it is important that all engineering controls are operating and that protective equipment requirements and personal hygiene measures are being followed. Only trained personnel should work with this product. Immediately report leaks, spills or failures of the safety equipment (e. ventilation system). In event of a spill or leak, immediately put on escape-type respirator and exit the area. Prevent uncontrolled release of product. Preve accidental contact with incompatible chemicals. Eliminate heat and ignition sources such as sparks, open flames, hot surfaces and static discharge. Post "No Smoking" signs. Use the pressure regulator appropriate for cylinder pressure and contents. Secure cylinder in an up-right position. Protect cylinders from damage. Use a suitable hand truck to move cylinders; do not drag, roll, slide, or drop.

Storage: Store in an area that is: cool, dry, well-ventilated, out of direct sunlight and away from heat and ignition sources, temperature-controlled. Always secure (e.g. chain) cylinders in an upright position to a wall, rack or other solid structure. Label container with date received, date opened and disposal date. Use a first-in, first-out inventory system. Empty containers may contain hazardous residue. Store separately. Keep closed. Comply with all applicabl health and safety regulations, fire and building codes.

▼

What is the American Conference of Governmental Industrial Hygienists (ACGIH®) recommended exposure limit for carbon monoxide?

ACGIH® TLV® - TWA: 25 ppm BEI

Exposure Guideline Comments: TLV® = Threshold Limit Value. TWA = Time-Weighted Average. BEI® = Biological Exposure Index.

▼

What are the engineering controls for carbon monoxide?

Engineering Controls: Use local exhaust ventilation, if general ventilation is not adequate to control amount in the air. Exhaust directly to the outside, taking any necessary precautions for environmental protection. Use non-sparking ventilation systems, approved explosion-proof equipment and intrinsica safe electrical systems in areas where this product is used and stored.

▼

What Personal Protective Equipment (PPE) is needed when working with carbon monoxid

Eye/Face Protection: Not required but it is good practice to wear safety glasses or chemical safety goggles.

Skin Protection: If there is a risk of contacting liquid CO: wear chemical protective clothing e.g. gloves, aprons, boots. Suitable materials (http://www.ccohs.ca/oshanswers/prevention/ppe/trade_name.html) include: Tychem® BR/LV, Tychem® TK, Tychem® TK.

Respiratory Protection: Up to 350 ppm: supplied air respirator. Up to 875 ppm: supplied air respirator. Operated in continuous flow mode. Up to 1200 ppm: wear a NIOSH approved self-contained breathing apparatus (SCBA) or supplied air respirator, wear a powered air-purifying respirator with an appropriate cartridge. ESCAPE: wear a NIOSH approved air-purifying respirator with an appropriate cartridge.

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Document last updated on January 17,

What's New

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Appendix Z:

Overview of Proposed BOMA IAQ Assessment Methodology

Pre-Assessment:

1) The Building Environment Unit (BEU) of the Government of Alberta (GOA), or a non-government organization with the necessary training and resources to conduct the assessment, receives an application from a Building Operator, Facilities Manager or similar person with the necessary authority, to conduct a BOMA IAQ Assessment in a GOA building.
2) Staff (Assessors) is assigned to conduct the assessment and are given the necessary building contact information to schedule an assessment.
3) Once the date and time of the assessment is set with the onsite operator, the assessors will contact the building operator to ask them if there have been any recent IAQ issues in the building. In addition, the assessor would ask the building operator to contact the building occupants to make them aware of the assessment so that if they have any IAQ concerns these can be brought to the operator's and assessor's attention before and during the testing. Furthermore, the building operator will be asked to indicate on floor plans of the building which spaces are occupied. Once the assessor receives them, the floor plans will be overlaid with the 6.7 m^2 grid pattern and random test spots will be chosen.
4) The assessor reviews the most recent BLIMS/ReCAP report for the building.
5) The assessor determines the random spot testing locations on a Floor Plan of the building.
6) Two (2) to three (3) days prior to the assessment has been scheduled, the assessor contacts the building operator to confirm the assessment.

Assessment:

1) In the morning of the date of the assessment the assessor meets the building operator at the building to begin the assessment.
2) The assessment begins by the assessor reviewing the assessment process with the building operator and asking if the AHU and associated systems are operating within design specifications.
3) Prior to inspecting the AHU together, the building operator and assessor are to walk through all occupied areas of the building so that the assessor is introduced to the building occupants. This is done not only so that the occupants know who the assessor is, the occupants can also discuss any preliminary IAQ concerns with the building operator and/or assessor.
4) The building operator and the assessor then start to inspect all of the AHUs, including: the perceived air quality next to the air intakes; if and how much the air intake dampers are open; condition of the pre/post filter chambers and condition of the pre/post air filters and related equipment.
5) Once the AHU inspections are complete, the assessor will walk back through all occupied areas to choose the appropriate number of non-random and random test locations. The location and number of non-random Spot Testing Locations will depend on information from the occupants and the observations of the assessor. The location and the number of Random Spot Testing Locations will depend on the number of non-random locations.
6) Assessor will take quantitative and qualitative measurements in the non-random and random Spot Test Locations:

6a) Quantitative parameters will be measured with IAQ equipment, including but not limited to the use of Direct-Reading Methods and sorbent tubes, specifically designed to record the IAQ parameters outlined in this methodology. To further reduce bias, the assessor will constantly and consistently follow the manufacturer's directions/instructions on the operation of the IAQ equipment. In addition, the NIOSH General Considerations for Sampling Airborne contaminants (NIOSH, 1998); OSHA (United States Department of Labour, 2015a) Sampling and Analytic Methods for Specific Chemicals and OSHA (United States Department of Labour, 2015b) Analytical Methods Manual, Indoor Air Quality Investigation should also be referred to. All IAQ testing equipment is to be regularly calibrated and properly maintained. The quantitative measurements will include: Comfort Parameters (Temperature, Relative Humidity, Carbon Dioxide and Carbon Monoxide); Dust (Ambient, Entrained Carpet and Entrained Chair and Work surface Dust); Supply Airflow and Air Pressurization; Total Volatile Organic Compounds; Formaldehyde and noting any associated observations related to these parameters.

6b) Qualitative observations will include interviewing the occupants to record their personal observations on their perception of the IAQ of their work area. The comments will be written down and reviewed with the occupants so that they are accurate and precise.

<u>Post-Assessment:</u>

1) On the day of the inspection, during and after the assessment, onsite verbal accounts will be given to the building operator, Alberta Infrastructure Facility Manager or Operations supervisor.

2) Limited overview of the IAQ results may be given to the occupants depending on explicit instructions from the building operator or Alberta Infrastructure Staff.
3) Within a month of the BOMA IAQ Assessment, a written report will be issued to the building operator and Alberta Infrastructure Staff.