Microenvironment Analysis of Homes with Attached Garages using
Volatile Organic Compound Source Apportionment Modelling

by

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Abstract

This thesis is based on an extensive air quality study in homes with attached garages conducted by Health Canada in Ottawa, Ontario. The thesis used source apportionment modelling to resolve sources that contribute to the home, garage and ambient volatile organic compound (VOC) concentrations, providing insight to common sources and infiltration between these microenvironments.

Six sources were identified for each sampling location including those related to global persistent compounds, fuel and other combustion processes, fuel evaporation and solvent use. The presence of these factors in more than one microenvironment combined with the statistical analysis conducted using correlations and ratios confirmed the likelihood of infiltration between the microenvironments.

This research supplements the Health Canada study and provides an alternative avenue for reducing the VOC concentration in homes by providing the opportunity to eliminate point sources within the home and garage.

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List of Nomenclature and Abbreviations

AER.....	Air exchange rate
APCS.....	Absolute Principal Component Scores
ASHRAE.....	American Society of Heating, Refrigerating and Air-Conditioner Engineers
BDL.....	Below Detection Limit
BTEX.....	Benzene, Toluene, Ethylbenzene, m-, o-, p-xylene
C3.....	Uncertainty increase (percentage)
CARA.....	Clean Air Regulatory Agenda
CAT.....	Capillary Absorptive Tube
CEPA.....	Canadian Environmental Protection Act
CFA.....	Conventional Factor Analysis
CMB.....	Chemical Mass Balance
CO.....	Carbon Monoxide
CO ₂	Carbon Dioxide
CRC.....	Chlorofluorocarbons
CV.....	Coefficient of Variation

DNPH.....	2,4-dinitrophenylhydrazine
E.....	Residual Error Matrix (nxm)
F.....	Factor Profile (pxm)
G.....	Garage
G.....	Matrix of Time Variations in Contributions (nxp)
GC-MS.....	Gas Chromatography - Mass Spectrometry
GRACE.....	Graphical Ratio Analysis for Composition Estimates
HCFC.....	Hydrochlorofluorocarbons
I.....	Indoor
IQR.....	Interquartile Range
m.....	Number of Species
MTBE.....	Methyl tert-butyl Ether
n.....	Number of Samples
NBCC.....	National Building Code of Canada
NO _x	Nitrogen Oxides
NRC.....	National Research Council

O.....	Outdoor
p.....	Number of Factors
PCA.....	Principal Component Analysis
PFT.....	Perfluorocarbon Tracer
PMF.....	Positive Matrix Factorization
ppbRAE 3000.....	Type of VOC monitor
Q.....	Goodness of Fit Parameter
Q1.....	First Quartile
Q3.....	Third Quartile
RAGI.....	Residential Attached Garage Intervention
S/N.....	Signal to Noise Ratio
SAFER.....	Source Apportionment by Factors with Explicit Restriction
SD.....	Standard Deviation
SUM15CEPA.....	15 VOCs identified as toxic under CEPA
SUM81VOC.....	81 species that remained after screening
T/B.....	Toluene-to-benzene Ratio

THC.....Total Hydrocarbons

TVOC.....Total 194 volatile organic compounds

US EPA.....United States Environmental Protection Agency

VOC.....Volatile Organic Compounds

X.....Matrix of Concentrations (nxm)

X/E.....Xylene-to-ethylbenzene Ratio

1 Introduction

This thesis is based on an extensive study of air quality in homes with attached garages entitled Residential Attached Garage Intervention (RAGI) conducted by Health Canada in Ottawa, Ontario. While the broader objective of the study was to analyze air quality and the effectiveness of two intervention strategies to minimize garage-indoor interaction, the thesis uses the volatile organic compound (VOC) measurements and aims to characterize their potential sources in support of the broader analysis.

The air we breathe is an important pathway for exposure to environmental pollutants, which may have a variety of sources. Ambient air quality criteria and regulations have addressed urban and rural air quality concerns with increasing effectiveness in most cases in recent decades. However, it is recognized that the indoor environment typically shows elevated concentrations of many compounds relative to ambient air, due to the presence of many small sources inside the home. The Canadian Human Activity Pattern Survey (Leech et al., 2002) identified activity patterns from almost 2,400 households in four major Canadian cities. This study indicated that approximately 66% of the participants' time was spent indoors at home.

Figure 1-1 illustrates the overwhelming magnitude of this time.

Figure 1-1: Activity patterns for Canadian households in the Canadian Human Activity Pattern Survey

This study demonstrates the importance of creating an indoor environment that is healthy for occupants. The American Society of Heating, Refrigerating and Air-Conditioner Engineers (ASHRAE) published a document stating their position on indoor air quality. It summarizes that indoor air quality directly impacts occupant health, comfort and work performance. By making the quality of indoor air a priority, the health and economic benefits are substantial on a national magnitude considering the amount of time spent indoors (ASHRAE, 2011). Factors that can affect the quality of indoor air can range from physical markers such as temperature and humidity to typically unnoticed chemicals such as volatile organic compounds (VOCs), carbon monoxide (CO) and nitrogen dioxide (ASHRAE, 2011).

VOCs are chemical compounds that readily volatilize into the atmosphere and can include over 500 organic species including alkanes, alkenes, alkynes, aromatics, aldehydes, ketones, acids, and alcohols (Kuntasal, 2005) (Mackay et al., 1992). The presence of VOCs

indoors can be of particular concern because of the many available emission sources. Household products such as paints, solvents, wood preservatives, aerosol sprays, cleansers, automotive products and dry-cleaned clothing can all be sources for VOCs (EPA, 2014). These common household items are also used extensively in new buildings and homes and new furniture can result in long-lasting sources of VOCs (Shin & Jo, 2012).

Numerous studies have indicated the significance of garages as contributors to the VOC concentrations found within homes (Batterman et al., 2006) (Graham et al., 2004) (Offerman et al., 2012) (Emmerich et al., 2003). Many of the aforementioned household items tend to be stored in the garage. Garage sources can also include small motor appliances such as lawnmowers, leaf and snow blowers, vehicles and solvents or chemicals that are readily volatilized. When vehicles and other combustion motors are started, especially those located in colder regions such as Canada, a rush of fuel is supplied to the motor to start the engine. This rush of fuel results in a surge of exhaust being emitted into the garage. Furthermore, while parked or stored in the garage, volatile compounds can off-gas from vehicles or other mobile equipment, most notably while cooling after use through hot-soak emissions. This creates a continuous source of VOCs available for migration into the home through the garage-house interface, or should a resident enter the home through the garage (Batterman et al., 2006).

Health Canada's Water, Air and Climate Change Bureau has identified this concern and have been involved in several studies that consider VOCs inside of homes, some of which consider the impact of attached garages. Most notably, Graham, et al.'s Ottawa study examined the contribution of vehicle emissions in attached garages on indoor air pollution

levels, with a focus on cold- and hot-start tailpipe emissions, hot-soak evaporative emissions and the affect that they have on indoor air quality. This study was conducted over winter seasons in 1997/1998 and 1998/1999 and also included a small section on chemical mass balance modelling (Graham et al., 2004).

Most recently, Health Canada lead a Residential Attached Garage Intervention (RAGI), which considered the significant impact that garages have on the indoor air quality and introduced interventions to reduce the magnitude of contribution. The main reason for garage air to enter the home is through the exchange of air between microenvironments. By lowering the pressure in the garage, it is less likely that the air will move from the garage to the home. Furthermore, this movement through a pressure difference is perpetuated by any holes or cracks in the interface between the home and the garage. The presence of these building issues provides a continuous source for air to move into the home, rather than simply maintaining to when the garage-to-home door is opened. Eliminating the two-abovementioned conditions would thereby greatly decrease infiltration. Therefore, the Health Canada study considered two interventions:

1. The introduction of an exhaust fan into the garage reducing pressure in the garage and thereby actively reversing the pressure differential, and
2. Improving the garage/house interface by sealing any cracks or leaks, a passive method requiring little to no maintenance and reduces the energy consumption within the home.

This study was conducted over two winter seasons in 2012/2013 and 2013/2014 at 36 homes in the Ottawa region to establish the contributions from the garage and ambient air

to the VOCs sampled in the living areas of the houses. The investigators in this also aimed to determine the effectiveness of the two intervention measures in reducing the contribution from the attached garage.

To complement Health Canada's RAGI analysis, source apportionment modelling was proposed for this thesis to recognize individual pollution sources within the home by identifying factors in each microenvironment. Therefore, this thesis hypothesizes that:

- i. Statistically significant relationships will be observed amongst indoor, garage and ambient samples, indicative of air exchange and VOC infiltration between microenvironments.
- ii. Receptor modelling will identify several major source types that contribute to indoor VOC levels and quantify their relative contribution to total VOC and total toxic VOC.
- iii. Sources identified by receptor modelling will help quantify source infiltration by demonstrating similarities between microenvironments and will establish differences between source types that are unique to a microenvironment, especially indoors.

This document will provide a brief review on relevant literature, outline the methodology used to conduct the RAGI study and report the results of a statistical analysis and source apportionment modelling of the obtained RAGI VOC sampling data using summa canisters in homes with attached garages. Results of the statistical analysis will be presented in Chapter 4 and those factors identified through source apportionment modelling will be explored in Chapter 5 of the document.

2 Literature Review

2.1 Background

The first studies on residential indoor air quality seem to be published in articles during the mid-1980s. Offerman et al. completed a study in 1982, which examined the effectiveness of construction techniques to reduce air leakage and overall air exchange rates (AER) in homes. In 1987, Sexton and Hayward examined source apportionment models for indoor air pollution to attempt to gain understanding of the relative contributions from sources. Their work however, was limited by an inadequate understanding of the modifications necessary to work indoors (Sexton & Hayward, 1987).

The use of a perfluorocarbon tracer (PFT) to measure the infiltration rate in residential homes was demonstrated in Dietz et al.'s work in 1982 (Dietz & Cote, 1982). It wasn't until R.B. Gammage's work in 1985 that the concept of migration of VOCs from gasoline fuels into the home environment was investigated (Gammage, 1985).

Currently, as more time is spent indoors the quality of air within those environments has been scrutinized in greater depth. As of 2005, Canadians spend on average 15.8 hours, or 66% of their day inside of their homes (Brasche & Bischof, 2005) and 80-90% of their time indoors (Mann et al., 1997). A number of studies, including those completed by Hun et al., (2011); Zielinska et al., (2011); Dodson et al., (2008); Batterman et al., (2007, 2006); Graham et al., (2004); and Emmerich et al., (2003) demonstrate that a variable percentage of harmful contaminants such as benzene, other VOCs and carbon monoxide can easily

migrate into the home from the attached garage. With the increase of time spent indoors, it becomes more important to find ways to reverse this contaminant transport.

2.2 Volatile Organic Compounds

Volatile organic compounds are compounds containing one or more carbon atoms and a higher vapour pressure that are inclined to evaporate readily to the atmosphere (Environment Canada, 2015). VOCs can include pure hydrocarbons or can be compounds containing oxygen, chlorine or other halogens such as aldehydes, alcohols, chlorofluorocarbons (CFC) and hydrochlorofluorocarbons (HCFC), which are very persistent compounds within the atmosphere (Kuntasal, 2005). Environment Canada identifies VOCs on their toxic substances list under Schedule 1 of the *Canadian Environmental Protection Act*, 1999 (CEPA 1999). VOCs are compounds of concern because of the environmental impact that they may have by acting as a precursor to the formation of ground level ozone, particulate matter and smog, as well as the human health impact which can include premature death, increased risk of lung cancer and heart diseases depending on the extent and length of exposure (Environment Canada, 2015).

VOCs can be emitted from numerous sources and activities including both anthropogenic and biogenic sources. Sources around the home such as combustion, smoking, household cleaning products, gas powered tools, personal care products, building materials and vehicle emissions can impact the concentration of VOCs found in the home (Dodson et al., 2008). Benzene, toluene, ethylbenzene and *m*-, *p*-, *o*-xylene, also known by the acronym BTEX, are examples of VOCs that can be associated with fuel storage. Batterman et al. (2007) state that VOCs such as benzene experienced by non-smoking individuals in homes

with attached garages are dominated by emission in garages and therefore, they suggest better control of VOC emissions in the garage and also better control of migration between the garage-home interface (Batterman et al., 2007).

2.3 Attached Garages as a Source of Volatile Organic Compounds

As previously mentioned, it was determined that benzene and other VOCs are found at higher levels within homes with attached garages. Dodson et al. (2008) determined that residences with attached garages had indoor BTEX concentrations that were 2 to 6 times higher than those without attached garages and found this observation consistent with findings from other studies completed by Batterman et al. (2007), Isbell et al. (2005), and Thomas et al. (1993). In addition to contaminant transport into the homes, Batterman et al. (2007) also observe that the garage may be considered a usable space to some homeowners and can be an area of the home that is used quite extensively for various activities. Spending additional time in the garage would increase the exposure, since the concentrations of VOCs from sources within the garage would be highest at the source. Additionally, it was noted by Weisel et al. (2008) that benzene in homes typically originated only from two sources—either from emissions from gas-powered vehicles and engines in garages or from evaporative emissions. This observation indicates that in addition to air exchange rates, benzene is a good marker to determine the extent of transport from the garage into homes and is valuable to study since it is a known carcinogen and harmful at higher levels (Weisel et al., 2008).

Several groups of researchers have studied the influence of attached garages on indoor contaminant concentrations where focuses include, but are not limited to the effect of: the

positioning of the garage, the operation of the vehicle parked in the garage and the tightness of the home, and have used chemical mass balance (CMB) modelling in their research to assess the contributing sources.

2.3.1 Location of the Garage

The location of the garage with respect to the house was studied to determine if it had an effect on the contribution to the indoor concentrations. For example, Graham et al. (2004) assessed the number of connecting walls the garage and home had and reported on the corresponding leakage rate to determine if there was any correlation. Generally, there were no extreme correlation between the numbers of walls shared and the percent of leakage in this study (Graham, et al., 2004).

Offerman et al. (2012) conducted a larger study to associate the garage location with infiltration, where the location was either under the house or beside the house. It was found that even though a trend was found where the leakage area was higher in homes that were above the garage, it was not a very significant difference.

Dodson et al. (2008) studied the influence of basements, garages and common hallways on VOC concentrations. During the study it was found that in general, garages lateral to the living space had a larger contribution to the indoor VOC concentrations than those below or attached to the basement. It should be noted though that for this study the rate of transport was higher for those homes with sub-lateral garages, the lower concentrations observed in the living space are due to the longer transport through the basement to that space. This

observation should influence home designers to design the living area to be as far away from the garage/home interface if possible (Dodson et al., 2008).

2.3.2 Vehicle Testing - Hot Soaks and Cold Starts

Zielinska et al. (2012) examined the vehicle type, the operational mode and the fuel type and compared the varying situations to the pollution levels in the garage as well as the adjoining room, which was the kitchen. The group compared a sedan and a full-sized V8 truck using a dynamometer, and compared exhaust emissions, fuel economy and specific VOCs. Additionally, three different fuels were used, baseline fuel, Methyl tert-butyl Ether (MTBE) fuel and ethanol fuel (Zielinska, et al., 2012). With these variables, different scenarios were set up in the test home including:

- Assessing initial pollutant levels,
- Hot soak conditions where the person coming home comes from the garage into the kitchen,
- Period where trapped garage air remains in the kitchen,
- Kitchen window open while garage door remains closed, and
- Cold start where car is warmed up on the garage for 30 minutes.

Results showed that the highest concentrations of emissions were observed during the cold start, regardless of the vehicle or fuel type. Generally, it was found that the truck resulted in higher concentrations of emissions in the kitchen, higher ambient temperatures resulted in higher concentrations of emissions in the kitchen and even without a vehicle present in

the garage there were high concentration levels in the kitchen due to storage of gasoline and a lawnmower (Zielinska, et al., 2012).

Cold-start and hot-soak emissions were also of concern with Graham et al. in their study published in 2004 and also found that cold-start emissions were consistently higher. The group characterized one light-duty vehicle, (comparable to Zielinska et al.'s sedan) which was tested using two fuels labelled "Fuel 1" and "Fuel 2". The vehicle exhaust was collected once it mixed with the ambient air and was analyzed for CO, CO₂, total hydrocarbons (THC) and NO_x. Furthermore, the car was placed in a constructed sealed housing with very limited leakage to determine the evaporative emissions. Samples were taken under simulated hot-soak and cold-start situations and analyzed. It was found that the cold-start emissions were much higher than if the car were to be started when warm and used more than twice as much fuel to start. The study continues to examine infiltration measurements and concentrations found within the home and the results are summarized in the following section.

The consistent findings between the two groups indicate that the emissions will be at a worst-case scenario during the Canadian winter when most people park their vehicles in attached garages. Starting these vehicles during the cold winter will yield in higher exhaust emissions as observed in the previous two studies mentioned.

2.3.3 Infiltration of the Home

Some studies have examined the influence on indoor residential VOC levels not only from garages, but from basements and common hallways in apartments as well. Dodson et al.

(2008) looked at 55 residences in Boston, Massachusetts, 11 of which had attached garages, 24 only had basements, 10 had common hallways and the remaining 10 were single compartment residences and were used as background indicators. The study found that concentrations in the garage were 5-10 times those in the home, and that approximately 20-30% of the contaminants found indoors that are linked to gasoline such as benzene, toluene and MTBE were contributed from the garage. Basements contributed 10-20% of the estimated indoor concentrations and approximately 5-10% of the concentrations were attributed to air from the hallway. The attached garage, which typically stores a car along with the possibility of storing gasoline, paints, oil, lacquers and yard/garden supplies was thus a major contributor to VOCs measured inside the home (Dodson et al., 2008). Thus, if the mechanisms by which the contaminants travel through the interface can be minimized, the extent of exposure to these contaminants can also be minimized.

As mentioned in Section 1 and Section 2.3.2, Graham et al. conducted source apportionment in Ottawa homes, in partnership with Health Canada. In addition to the vehicle emission testing they did, infiltration measurements were completed to determine the leakiness of the house. It was determined that on average, approximately 11% of the total house leakage occurs between the garage/house interface (Graham et al., 2004). This leakage is approximately equal to the infiltration that would have resulted from an opening with a 24 cm² cross sectional area opening. Once this was determined, samples were collected during hot-soak and cold-start conditions outside and inside the home. These samples were analyzed for approximately 175 VOCs, 24 carbonyl compounds, methane, carbon monoxide and carbon dioxide. It was found that there is a measurable contribution to the indoor CO, CO₂ and VOC concentrations from the attached garages. Carbonyl

compounds were only expected to be present in exhaust during the cold-start test and not during the hot-soak since carbonyl compounds are a product of the combustion process. It was found however that changes in these concentrations were too small to be accurately measureable and therefore were not included in this study (Graham et al., 2004).

Emmerich et al. (2003) completed a small study on the air and pollutant transport from attached garages to living spaces for five homes in Washington D.C., each characterized by the type of home. Because of the small sample size, the group was unable to draw larger inferences but using blower door testing, they were able to determine that the garages were at least twice as leaky as the living space and that the older houses tended to be leakier than the newer.

Batterman et al. (2007) investigated the migration of pollutants from garages to adjoining houses in 15 homes in southeast Michigan. The group continues their study that was published in 2006 and looks at ways to quantify airflow and migration between zones using a two-tracer two-zone system measurements of VOCs and what may affect the VOC levels at varying locations. PFTs were used as tracers to determine the AER between zones, which averaged $0.43 \pm 0.37 \text{ h}^{-1}$. As shown by the high error value, there was a wide distribution in AERs throughout the homes tested. Airflows between the garage and home interface averaged $9.3 \pm 5.7 \text{ m}^3/\text{h}$, which is about $6.5 \pm 5.3\%$ of the entire home.

The presence of 39 target VOCs were detected in the home, 36 of which were found in the garage and 20 of which were in the ambient air. The results of the sampling were used to calculate garage/indoor concentration ratios to determine the extent of impact of garage

sources in the home. The median Garage/Indoor ratio for benzene was 16.6, indicating dominance of garage sources migrating into the homes (Batterman et al., 2007).

Lastly, in addition to examining the effect that positioning of the garage had on leakage rates, Offerman et al. (2012) also looked at characterizing leakage areas and factors that affected these areas. Using a group of 105 homes in California, the research group collected information on VOCs and air exchange rates using evacuated stainless-steel canisters and PFTs, respectively. It was found that in 60% of the homes, the garage was situated below the living space and the remainder had the garage to the side. Of these garages, more than 90% of them were used for vehicle parking. Using the PFTs and blower door testing, it was found that the median air change rate was 0.26/h. It was found that of the 60 VOCs analyzed for, 10 were above $10 \mu\text{g}/\text{m}^3$ and 3 were above the hazard quotient calculated by the Office of Environmental Health Hazard Assessment's Chronic Reference Exposure Levels (OEHHA's CRELs). These were benzene, toluene and xylene and therefore, were focused on throughout the study (Offerman et al., 2012).

The concentration differences between indoor and outdoor (I-O) values were <0.3 , 1.2 and $1.2 \mu\text{g}/\text{m}^3$ for benzene, toluene and xylenes, respectively. It was determined that even though the values found were typically less than guidance values, the presence of the garage significantly increases the inhaled dose of BTEX. Upon comparison with other reports, it was found that the homes studied in California are representative of those in other sets of other North American homes (Offerman et al., 2012).

Other contaminants and parameters such as carbon monoxide, carbon dioxide, aldehydes, carbonyl groups and ventilation rates have been examined in literature and through the

RAGI study, but it was determined during this study that VOCs would be focused on for source apportionment purposes.

2.4 Source Apportionment Modelling

Air pollution from non-reactive compounds is commonly modelled through one of two types of models: receptor models or dispersion models. Dispersion models are useful for modelling the movement of pollutants in ambient air and predicting concentrations at specific receptor sites.

Source apportionment is a form of receptor modelling that is concerned with identifying the contribution of different source types to concentrations measured at receptor sites so that effective control actions can be undertaken. If potential sources have been characterized, Chemical Mass Balance can be used to estimate the percentage contribution of important emission sources. If sources are unknown, Positive Matrix Factorization (PMF) can be used with a sizeable amount of ambient measurement data to distinguish sources (Environment Canada, 2013). The U.S. Environmental Protection Agency endorses three models used in air quality management: Chemical Mass Balance (CMB), UNMIX and Positive Matrix Factorization (PMF).

CMB uses source profiles consisting of the fraction of each chemical species emitted by each source type, and the same suite of species measured at receptors (Coulter, 2004). Assuming several conditions are met including that emissions are constant, species are non-reactive and all possible sources are included in the equation, CMB uses the effective

variance weighted solution to provide the most likely source contributions to the measured receptor concentrations (Coulter, 2004).

UNMIX is an advanced multivariate receptor model developed by the US EPA, which identifies contributing sources measured in the ambient air using a form of factor analysis. This model does not require a source profile as in CMB but uses sample species concentrations and the identification of edges where contributions of a source are not present compared to other sources to calculate the relative contributions (U.S. Environmental Protection Agency, 2013) (Song, et al., 2008).

Similar to UNMIX, PMF also uses factor analysis and user inputted sample species concentrations but also includes user-inputted uncertainties to create matrices of factor contributions (G) and factor profiles (F) to be interpreted and connected to reasonable source types (Norris et al., 2014). Unlike UNMIX, it is possible to individually weight data points with PMF, which is highly useful when applied to this research as it incorporates the inevitable uncertainties that accompany the analysis of such a large species suite in highly variable indoor environments (Norris et al., 2014).

Research by Pekey et al. (2006) and Poirot et al. (2001) indicate that major factors identified from PMF and UNMIX are generally similar in nature, however UNMIX may not resolve as many factors as PMF.

A study conducted by Huang et al. in 1999 compared the theoretical aspects of PMF to conventional factor analysis (CFA). They considered ways of handling missing data, using logarithms of concentrations, choice of elements and the number of factors applied to each

analysis method. This analysis noted that although PMF had some disadvantages such as the requirement that input data must be prepared by hand, missing values must be eliminated or filled in manually, factors are not presented in a systematic order and more time is required by the analyst than with CFA, it was determined that PMF has clear advantages leading to significantly better results. PMF was found to use information more efficiently, separated sources better than CFA, and provided more useful output information than CFA (Huang et al., 1999).

Historically, the majority of use for receptor modelling has been for the analysis of particulate matter, however in recent years, application to VOCs analysis has become more popular. Huang et al. refer to the beginning of environmental application of PMF by Junto and Paatero (1994), Anttila et al. (1995) and Polissar et al. (1996) who investigated daily precipitation data, bulk wet deposition and optical absorption coefficients with respect to sulphur concentrations, respectively. Studies by Polissar et al. (2001), Li et al. (2004), Kim et al. (2003; 2004), Zhao and Hopke (2004) and Owega et al. (2004) collected fine particulate data and assessed using PMF in Vermont, USA; New York, USA; Atlanta, USA; San Gorgonio, USA; and Toronto, Canada, respectively. This incomplete list of studies indicates the extensive nature of the application of PMF to particulate matter analysis.

One of the first applications of PMF to VOCs was by Anderson et al. (2001), where PMF was used to quantify personal exposure and outdoor concentration sources. Anderson et al. (2002) then conducted an evaluation of receptor models using simulated exposure data and an application of receptor models to the US EPA's TEAM study (Anderson et al., 2002).

The models compared were CMB, principal component analysis (PCA), absolute principal component scores (APCS), positive matrix factorization (PMF) and graphical ratio analysis for composition estimates (GRACE), source apportionment by factors with explicit restriction (SAFER) incorporated into the UNMIX model. The authors of these evaluations concluded that the PMF model appeared to extract major source profiles the best amongst comparable receptor models. There was difficulty noted in differentiating between similar source profiles such as auto exhaust, environmental tobacco smoke and gasoline vapours (Miller et al., 2002). The second part of this study where PMF was applied to actual TEAM data resulted in the identification of six significant sources. Studies that contain this information are extremely useful when comparing to current results to aid in interpretation. Zhao et al. used PMF in 2004 to identify sources of VOCs in Houston, Texas. This study identified nine sources in the Houston area, some of which included different types of chemical plants and refineries as well as biogenic sources (Zhao et al., 2004). Jorquera and Rappengluck also conducted analysis of VOC data in Santiago, Chile at downtown and residential sites using both UNMIX and PMF. This study resulted in approximately 70% of ambient VOC sources at both sites interpreted as mobile sources (Jorquera & Rappengluck, 2004). In 2007, Song et al. conducted a VOC source apportionment study using PMF in Beijing, China with samples taken from a roof of a five-story building. This also identified eight sources, the majority of which include mobile and biogenic sources (Song, et al., 2007). There are a number of other PMF source apportionment studies in other outdoor locations, which include those conducted by Brown et al. (2007) in Los Angeles, USA; Cai et al. (2010) in Shanghai, China; Lam et al. (2013) in Hong Kong,

China; McCarthy et al. (2013) in Edmonton, Alberta; and Yurdakul et al. (2013) in Ankara, Turkey.

In addition to the list of researchers that used PMF to analyze ambient conditions, there are also studies that analyze indoor microenvironments. In 2011, Guo published a study involving source apportionment of volatile organic compounds in 100 Hong Kong homes but used PCA rather than PMF. This study led to the identification of major sources such as building materials off-gassing, household products, painted wood products, room freshener, mothballs and consumer products (Guo, 2011). However, as per the Miller et al. (2002) study, PMF tends to extract profiles that most closely represent the actual sources. Most recently, Bari et al. (2015) analyzed indoor and outdoor VOCs at homes in Edmonton, Canada using source apportionment. The researchers in this study used PMF to identify 13 indoor and 10 outdoor factors. Despite the large number of factors for each microenvironment, 44% of the indoor VOCs were attributed to household products, followed by combustion by-products contributing 10.5%, deodorizers 8.4% and building materials 5.9%. Outdoor sources included industry sources, mobile sources, background and biogenic emissions (Bari et al., 2015). A large portion of these sources is also represented in the above-mentioned studies, indicative of major sources to consider for analysis of current data.

Very few studies have sampled in attached garages, with no apparent studies combining PMF analysis with garage VOC sampling. Bari et al. reference attached garages in their publication by identifying the number of homes that are influenced by attached garages and identified PMF-identified sources within the home that would be present due to an

attached garage (Bari et al., 2015). As mentioned previously, Graham et al. (2004) used CMB modelling to estimate source contributions. They determined that between 9 and 71% of concentration found in the home can be attributed to vehicle emissions during hot-soak and 13 to 85% during cold-start (Graham et al., 2004). The scope of the source apportionment work however, remains focused on vehicle emissions related to operation conditions.

This research can thus make a contribution to closing a gap in the application of PMF source apportionment methodology to homes with attached garages.

2.5 Building Standards and Possible Interventions

Based on the literature published, there has been extensive research conducted on infiltration and how attached garages influence the indoor concentrations of certain contaminants. It has been determined that VOCs are of major concern with other parameters including CO, CO₂, carbonyl groups and microenvironment air exchange rates.

There seems to be a lack of information or research regarding ways to address the higher VOC concentrations observed in homes with attached garages. Even though minimum ventilation requirements for indoor environments are available through the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), there are no requirements for any type of exhaust ventilation in the garage. Furthermore, with newer homes focusing on air-tightness to reduce energy consumption, contaminants that infiltrate the home from the garage typically will remain in the home longer than in an older, leakier home (Nirvan et al., 2012). According to the current National Building Code of Canada

(NBCC) there are several requirements for an attached garage that include: “the garage floor must be sloped to the outdoors” or “an airtight curb or partition not less than 50 mm high be installed at the edges of the garage floor adjacent to interior space” if the garage accommodates fewer than 3 vehicles. The NBCC does not require any ventilation in garages with 4 cars or less, but requires a mechanical ventilation system for those with 5 cars or more (National Research Council Canada, 2010).

According to Article 9.10.13.15 under the Ontario Building Code Act, 1992:

(1) A door between an attached or built-in garage and a dwelling unit shall be tight-fitting and weatherstripped to provide an effective barrier against the passage of gases and exhaust fumes and shall be fitted with a self-closing device.

(2) A doorway between an attached or built-in garage and a dwelling unit shall not be located in a room intended for sleeping.

Although the transfer of gases and exhaust are addressed in this code, the extent of the regulations is limited and weather-stripping tends to become less effective as houses age. Also, there are no articles that address ways to mitigate the concentrations within the garage.

The United States Environmental Protection Agency have created an Indoor airPLUS designation which allows homes to be certified with more robust specification and more requirements to be met to improve indoor air quality (Mudarri, 2010). Some of the requirements to be an Indoor airPLUS home are as follows:

- Attached garages are required to be isolated from a conditioned space through air sealed common walls;
 - Doors between homes and garages must be automatically closing and have gasket or weather stripping material present;
 - Attached garages shall include an exhaust fan venting directly outdoors; etc.
- (Mudarri, 2010).

These new designations in the United States are signs that the building code will develop to include possible solutions to these higher concentrations. However, the completion of a study on possible solutions and the positive impact which certain interventions may have on the home and health of occupants will hopefully bring more attention to this issue.

Sandel et al. (2010) discuss possible interventions that provided inspiration for the interventions to be studied in Ottawa. Some included re-sealing the garage, maintaining a negative pressure in the garage, sealing penetrations from the living area to the garage and taking administrative measures such as parking the car outside (Sandel, et al., 2010). Although these interventions have been suggested, the effects of these interventions haven't been adequately covered. This is the reasoning behind choosing to study the effect of maintaining a negative pressure in the garage through use of an exhaust fan, as well as the effect of sealing the garage/home interface better.

3 Methodology

The author of this thesis participated in the collection of data in Health Canada's RAGI study, and analyzed parts of the collected data with the objectives earlier identified in Chapter 1, via the use of receptor modelling to identify sources contributing to indoor VOC concentrations measured and the quantification of infiltration between microenvironments. The description of the methodology is based on Health Canada's study protocols (Wheeler, et al., 2012). All the field data collection is mentioned and documented in the sections below, the components not related to the receptor modelling analysis to come in the next chapters is mentioned only in summary.

3.1 Health Canada Residential Attached Garage Intervention (RAGI)

Prior studies within the Indoor Air program under the Clean Air Regulatory Agenda (CARA) revealed the extent of the exposure levels and potential pollution sources in Canadian residences. Studies which consistently showed the connection of higher pollution levels in homes with attached garages prompted phase three of CARA, which focused on reducing indoor air pollutant levels in residences in Canada. The RAGI study was conducted in collaboration with the National Research Council Canada – Construction Portfolio (NRC) to:

- Characterize the sources and levels of pollutants coming from attached garages into homes as well as the transfer level/rate;

- Test the effectiveness of two different interventions; installing a ventilation fan and sealing the interface between the garage and the home to reduce infiltration of pollutants into homes; and
- Refine advice to Canadians for reducing exposure to VOCs in homes with attached garages and to inform changes to the National Building Code of Canada.

3.2 Study Location and Participant Selection

The study was conducted in randomly selected homes sprawled across Ottawa, Ontario. The targeted sample size of thirty-six homes—plus ten to twenty percent to account for withdrawals—was recruited using a formal random digit dialling procedure. The participants selected satisfied the following inclusion criteria:

- Be residents of Ottawa;
- Be the owner-occupier of a single detached home, semi-detached home or row house/ Townhouse;
- Over 18 years of age;
- Able to complete questionnaires in English or French;
- Be physically and mentally capable of participation;
- Be non-smoking households;
- Have no commercial activities run out of their home;
- Must have an attached garage with a connecting door to the dwelling;

- Must have either an attached garage by a closed breezeway, an attached garage sharing only one wall, a basement garage or an integrated/built-in garage in which a fan can be installed easily;
- Must agree to have a fan installed in the garage and for the garage to be sealed between the home and the garage.

The selection process returned forty-five participants that were randomly sprawled across the city.

3.3 Sampling Schedule

The study was split into two years of sampling with the introduction of an intervention slated for each year. Appointments were scheduled mostly in the evenings while families are typically home and sampling required two weeks of visits to accommodate a week of pre- and post-sampling. As a field technician, in addition to writing this thesis, it was possible to accurately understand the study and sampling methods as well as the limitations encountered during the fieldwork.

3.3.1 Fall 2012

The first visits were brief, occurring in the months of October, November and December of 2012. The purpose of the initial visit was to:

- Meet the participant,
- Survey the home for eligibility,
- Present the summary of the study and to establish participant consent,

- Conduct a baseline questionnaire,
- Conduct an evaporative emissions questionnaire, and to
- Conduct the blower door test.

This meeting allowed for an assessment of the home and negated some of the participants' eligibility as some homes had very leaky garages or garages that could not have an exhaust fan installed.

The baseline questionnaire, which is shown in Appendix A: Example of Baseline Questionnaire was the method for collecting data regarding the participants' daily activities i.e. cooking, wood burning, etc., and details about their home that could potentially affect results. Examples of this information included the age of the house, furniture, carpeting, and whether the house had any renovations affecting the tightness.

The pilot evaporative emissions questionnaire was administered to create an inventory of the items typically stored in the attached garage and to identify the primary uses for the garage. Having access to this inventory of materials and products in the garage provided supplemental information to consult, if necessary, for potential sources of emissions such as lawnmowers, lawn care products, paints and gasoline.

A blower door test was administered during the fall visit using an Orifice Blower Door according to the American Society for Testing and Materials' (ASTM) test method E779-03 (ASTM, 2003) to assess the air tightness of the home. The equipment was installed in the doorframe of the front door and blew air in or out of the house to create a positive or negative 50 Pa pressure difference between the home and the outdoor microenvironments.

Those homes with a better seal required less power to create the pressure difference. It was ensured that all exterior doors and windows were closed and all interior doors remained open. All combustion appliances were turned off and all fireplaces and wood stove doors were closed. Any fans or air conditioners were turned off, and the thermostat setting was recorded and set so that it wouldn't turn on during the test. A qualified contractor performed two air leakage tests, including house only and garage only. Once the tests were run, the results were provided to Health Canada/NRC for analysis. These results aided in the selection of an exhaust fan appropriate for the size and the air leakage rate of the home and garage. The fan installation occurred prior to sampling and was sealed for pre-intervention sampling to allow for pre- and post-intervention sampling to occur consecutively.

3.3.2 Winter 2013

The homes were organized into three two-week randomly chosen cohorts. Each cohort was two weeks long in order to obtain three 24-hour samples each for pre- and post-intervention conditions. The participants were provided with a 24-hour daily activity questionnaire, which documented activities that may have affected results such as cooking with oil or gas appliances, applying cleaners or solvents or opening windows in the home. The sampling equipment was arranged in each of the microenvironments, deployed and details were recorded. Daily visits involved exchanging expended sampling equipment for a fresh sample and ensuring that weekly loggers were accurately deployed and actively logging. Following the first week of pre-intervention sampling, the garage exhaust fan was unsealed and post-intervention repeated the same process with the exhaust fan running.

3.3.3 Winter 2014

The second year of the study was dedicated to the second intervention. The first exhaust fan intervention described in Section 3.3.1 was duplicated to provide a higher level of confidence in the results of the air exchange rates between the garage and home and the home and outdoor microenvironments. Additionally, the sealing intervention was introduced where a specialist was contracted to assess and improve the seal between the home and garage. The replication of the fan intervention occurred prior to the installation, which also provided pre-intervention results. Following, the contractor improved the seal and sampling followed. Due to variability amongst homes, the exact same sealing procedure could not be applied throughout the homes and required modifications to suit what the house required.

3.4 Air Quality Parameters and Instrumentation

The parameters and the devices used to measure the parameters are summarized in Table 3-1 below.

Table 3-1: Pollutants of interest and corresponding equipment used

	Parameters	Devices	Sampling period
Indoor (Living room)	Nitrogen dioxide (NO ₂)	Ogawa samplers	24-hour
	Nitrogen oxides (NO _x)	Ogawa samplers	24-hour
	Volatile organic compounds (VOCs)	Summa canisters	24-hour
	VOCs	Perkin Elmer TA 60/80	72-hour
	Aldehydes	Waters SepPak Cartridge	72-hour
	Carbon monoxide (CO)	Langan CO monitors	1-min
	Carbon dioxide (CO ₂), Temperature, Relative Humidity	YES-206 monitors	1-min
	Ventilation rates	PFT/CAT	72-hour
Indoor (Garage)	NO ₂	Ogawa samplers	24-hour
	NO _x	Ogawa samplers	24-hour
	VOCs	Summa canisters	24-hour
	VOCs	Perkin Elmer TA 60/80	72-hour
	Aldehydes	Waters SepPak Cartridge	72-hour
	CO	Langan CO monitors	1-min

	CO ₂ , Temperature, Relative Humidity	YES-206 monitors	1-min
	Temperature (for CATS and PFT)	Onset Hobo U12-013	1-min
	Ventilation rates	PFT/CAT	72-hour
	Sensors	To be determined	Continuously
	Blower door test	Minneapolis Blower Door with TECTITE™ software	1-hour
Outdoor (Backyard)	NO ₂	Ogawa samplers	24-hour
	NO _x	Ogawa samplers	24-hour
	CO ₂ (one location)	Vaisala Inc. TBD	1-min
	VOCs	Summa canisters	24-hour
	VOCs	Perkin Elmer TA 60/80	72-hour
	Meteorology	Wind speed, direction, temperature	Continuous

Instrumentation for the abovementioned parameters is summarized in the following subsections.

3.4.1 Summa Canisters

VOCs were collected using three different measures in order to capture the full range of VOCs. 6.0 L Summa canisters equipped with 24-hour flow regulators were used indoors, outdoors and in the garage to capture a range of 193 VOCs. The start and finish canister

pressures were recorded for quality assurance to determine that a reasonable volume of ambient air was collected over the 24-hour period. These canisters were analyzed using gas chromatography-mass spectrometry (GC-MS) by Environment Canada's laboratory. The full suite of these species is provided in Appendix B: List of VOCs Analyzed using Summa Canisters.

3.4.2 Perkin Elmer Thermal Desorption Tubes

Perkin Elmer passive radial diffusive samplers packed with a Tenax TA 60/80 sorbent were used to sample a secondary suite of 73 VOCs including aromatics except for benzene, polar compounds and less volatile compounds (Perkin Elmer, 2015). The tubes used over a 72-hour sampling period rather than the 24-hour Summa canisters. The tubes were deployed in the indoor and garage locations with a blank tube in either location for quality assurance. An aluminium diffusion cap was applied to ensure an equal diffusion rate.

3.4.3 ppbRAE 3000

The ppbRAE uses a pump to pull in ambient air and actively records the total VOC concentration (RAE Systems, 2010). The ppbRAE was calibrated at the Health Canada laboratory before use with known concentrations of isobutylene. The ppbRAE was placed in the garage and living area of the home and was run for the entire 72-hour sampling period. Technicians ran the ppbRAE with a zero filter attached to the inlet at each 24-hour interval and recorded the displayed concentration to determine if there was any variance between the theoretical and actual reading. Any variance would be corrected for on the downloaded data.

3.4.4 Ogawa Samplers

Ogawa samplers were used to collect nitrogen dioxide (NO₂) and nitrogen oxides (NO_x). These samplers use diffusion to collect contaminants on two collection pads on either side of the sampler housed between two stainless steel screens in the inlet chamber.

Samples were collected in the living room, garage and outdoors. Ogawa sample blanks were used for quality control. The Ogawa sampler was clipped onto the Summa canister and the time of deployment was recorded on the log sheet. Samples were analyzed by ion chromatography.

3.4.5 Waters SepPak 2,4-dinitrophenylhydrazine (DNPH) Cartridge

Waters SepPak ExPosure cartridges were used to measure the aldehyde levels over a 72-hour sampling period and analyzed using high performance liquid chromatography. These samplers were deployed in the garage and indoors. A blank in either microenvironment was maintained for quality assurance purposes.

3.4.6 Langan T15n Carbon Monoxide (CO) Sensor

Carbon monoxide was measured in the living space of the home and in the garage. The sensor was placed on a table or flat surface and left on for the 72-hour sampling period and active data was downloaded and reviewed at the Health Canada laboratories.

3.4.7 Onset HOBO Data Loggers

Onset HOBO data loggers were used to log temperature, relative humidity, carbon dioxide and any external sensors necessary such as door sensors or pressure sensors. These data

loggers were left for the entire sampling period and downloaded at the end of the sampling period.

3.4.7.1 Door Sensors

Activity in and out of the garage was monitored using door sensors attached to a HOBO data logger. Door activity was logged at the garage door, the garage-home interface door and any other external doors from the garage to the exterior of the home.

3.4.7.2 Differential Pressure Sensor

The Differential Pressure sensor was placed at the garage-home interface to monitor the difference in pressure between the two microenvironments. The sensor was tared using the zero button and tubing was fed from the garage into the home. This sensor was also attached to the Hobo sensor to actively record the pressure differential.

3.4.7.3 Carbon Dioxide (CO₂) Sensor

Carbon dioxide was only measured indoors as an indication of ventilation. The carbon dioxide sensor was connected to the HOBO data logger to actively record the varying concentration.

3.4.8 Perfluorocarbon Tracer (PFT) and Capillary Adsorption Tube (CAT)

The average air exchange rate (AER) between the home and garage was recorded using the passive tracer gas technique or the PFT technique. Treating the home and garage as separate zones and emitting the inert perfluorocarbon tracer (PFT) at a constant rate, the air exchange rate can be determined through the amount absorbed onto a capillary

absorptive tube (CAT). The PFT was emitted constantly over the 72-hour sampling period, scaled to the size of the home.

3.5 Ethical Considerations

As with any study, the privacy of the participants was an important factor to consider, ensuring homeowner participation and retention. There were no health risks to the participants throughout this study. The homeowners' personal information was securely stored and each home was assigned a RAGI identification number to prevent any identification or bias. All information collected was linked to that number only.

Any correspondence requiring transmission of personal information was conducted through exchanged of physical documentation and was shredded. This included correspondence between Health Canada and the recruiting company or the contractors.

The completed questionnaires were inputted into an online survey tool that allows easy data export and analysis, however this was also inputted using the unique identifier.

3.6 Quality Assurance and Quality Control

Due to the nature of the study and the resources available, teams of technicians were assigned to specific homes for the entire sampling period, however there were several teams of technicians to complete the entire group of homes. This introduces the possibility of inconsistency between sampling and placement of equipment. To attempt to ensure consistency, in addition to extensive technician training, a technician was assigned to

quality control involving visits to all teams within a night to observe installation techniques and placement.

Where resources permitted, blanks or duplicates were applied to ensure there is no background influence requiring adjustment of the result or to provide confidence to the results obtained. These blanks or duplicates were commonly available for aldehyde analysis with the SepPak DNPH Cartridge, NO_x analysis using Ogawa samplers, VOC analysis using summa canisters and Perkin Elmer tubing and at some homes, VOC analysis using the ppbRAE. The ppbRAE required calibration since it was actively sampling throughout the week. This was conducted using zero tubes which allowed the technician to record the VOC reading should it not display the anticipated zero reading. Contamination through recycling flow regulators for the summa canisters was also considered and therefore following use within a home, the regulators were sent for cleaning to avoid any cross-contamination.

Following data collection, the summa canister VOC results were scrutinized using summary statistics and an outlier analysis as described in Section 4.5 and Section 4.6.4, respectively. These homes with outliers were further investigated to determine possible reasoning for the outlier sample. Furthermore, data with a high number of samples that were missing or below detection limit were considered for removal or down-weighting to uphold the quality of data and results.

3.7 Source Apportionment Methodology

Source apportionment modelling uses the conservation of mass principle and statistical analysis to identify sources of air pollutants and their contributions to the measured receptor concentrations (U.S. Environmental Protection Agency, 2013). Model outputs quantify the contribution of sources to receptors, identifying those that contribute greatly and those that have little effect on the ambient profile (Environment Canada, 2013).

This chapter applies the Positive Matrix Factorization (PMF) model to the three microenvironments studied in the RAGI field work and identifies the factors that are the sources of the observed concentrations of volatile organic compounds in the outdoor, garage, and indoor microenvironments.

3.7.1 PMF Model Description

As described by the User Guide for PMF (Graham et al., 2004), PMF is a multivariate factor analysis tool that decomposes a matrix of sample data into two matrices. The basic equation that describes the PMF model is shown in Equation (1):

$$X = [G \times F] + E \quad (1)$$

where X is the $n \times m$ matrix of concentrations where n is the number of samples and m is the number of species, G is the $n \times p$ matrix of time variations in contributions, F is the $p \times m$ factor profile, and E is the residual error matrix, $n \times m$ (Reff et al., 2007). This can also be written in simple algebraic format as Equation (2):

$$x_{nm} = \sum_{k=1}^p g_{nk} f_{km} + e_{nm} \quad (2)$$

where x_{nm} is the concentration of species (m) measured on sample (n), p is the number of factors contributing to the samples, f_{km} is the concentration of species m in factor profile k , g_{nk} is the relative contribution of factor k to sample n , and e_{nm} is the error of the PMF model for species m in sample n (Reff et al., 2007).

The error of the model is quantified by the difference between the measured concentration and the sum of the contributions from p sources estimated by the model and can be calculated using Equation (3).

$$e_{nm} = x_{nm} - \sum_{k=1}^p g_{nk} f_{km} \quad (3)$$

The model attempts to minimize object function Q , which is the sum of the errors of all the species in all the samples, weighted inversely with the uncertainty associated with each measurement. The equation for Q is described as such:

$$Q(E) = \sum_{i=1}^n \sum_{i=1}^m \left(\frac{e_{nm}}{\sigma_{nm}} \right)^2 \quad (4)$$

where σ_{nm} is the uncertainty of the measurement of species m in sample n (Reff et al., 2007).

In order to minimize the sum of errors, the user must specify the number of factors, species to include and the weight or influence of the species.

3.7.2 Model Input

A sample species concentration file and a sample species uncertainty file are the required inputs files to run PMF. Should any data be missing due to sampling error, missing data is typically identified within the concentration file using the indicator -999, and can be excluded or replaced with the species median as specified by the user in the PMF input page. The uncertainty values can either be estimated individually by sample and species, or by applying a formula to all samples based on method detection limits, percentage sampling and analysis errors specific to each species.

Within the PMF interface, the user may also assign change how strong a species is weighted. Species may either be categorized as strong, weak or bad. PMF will consider this categorization and treat strong species as normal and maintain the uncertainty identified in the file, include weak species but increase the uncertainty by three times and bad species are excluded altogether from consideration in the modelling. The threshold for inclusion of species based on signal to noise ratio in literature is variable. McCarthy et al. (2013) reports a S/N greater than 2.5 was required for inclusion to their analysis. The US EPA user guide suggests a conservative approach of “bad” if less than 0.5 and “weak” if greater than 0.5 but less than 1 (Norris et al., 2014). As per the Multivariate Receptor Modelling Workbook prepared for the US EPA by Sonoma Technology Inc. and Lockheed Martin, the S/N ratio should be greater than 1 and any species lower than that should be removed (Norris et al., 2008).

Prior to running, the user must also identify the number of factors that PMF must model. Zhao et al. (2004) use a series of three rules to decide what the best number of factors is, where:

1. the resolved sources should be physically explainable;
2. A change in the slope of the Q vs. p relationship from steep to shallow indicates that the improvement in the model is becoming marginal with increasing number of factors;
3. satisfactory fit between predicted concentration and measured values.

Using rule 2 identified above, a varying number of factors between 4 and 9 were modelled and the resulting Q value was plotted for each microenvironment to determine a starting point for the ideal number of factors to model.

Once this is determined, the model is run iteratively, changing the weights of the species to reach the ideal solution. This iterative process is outlined in Figure 3-1 below (Reff et al., 2007). The following section discusses the diagnostics used during analysis to assess the model fit.

Figure 3-1: Work flow diagram for PMF Analysis

3.7.3 Model Output and Diagnostics

The key outputs of the PMF model are G and F matrices as described in Section 3.7.1 above. The factor profiles F are established by the complete dataset, while the contributions G vary among samples. These results are presented graphically by the user interface as shown in the figure below.

Figure 3-2: Example of the graphically presented Factor Profile and Concentrations output in the PMF user interface

The example in Figure 3-2 shows the profile for Factor 1 (top) from two perspectives:

- “% of species” (squares) scale shows what percentage of the observed loadings for each species can be attributed to this particular factor. It is therefore not a profile of the factor *per se* (i.e. the percentages do not add up to 100, rather the percentages of a particular species displayed for each of the factors found would add up 100).
- The “Conc. of species” (bars) is a true profile in that it demonstrates the relative abundances of each of the species in the profile. Due to the logarithmic scale and concentration units used it is difficult to see the differences between different factors very easily but the results written to output files enable later comparisons in normalized linear scales.

The bottom graph shows the contribution of each factor to the total mass by sample. The bottom graph may be presented as shown with the concentration on the y-axis or may be scaled to represent normalized concentrations, which allows for a comparison of temporal patterns (Norris et al., 2014).

Issues that arise during this optimization problem includes questions as to whether the minimum is local or a global minimum, the optimal number of factors is selected since this is unknown to the user and whether the minimum value found is unique. The model interface produces complementary diagnostic tools, which enable the critical evaluation of the results for the robustness of the results and their sensitivity to choices made during the modelling. Output files containing different categories of results can be saved and used in

analysis of the calculated sources. These additional tools and results are briefly discussed in the following sections.

3.7.3.1 Residual Analysis

The residual analysis reports the distribution of residuals for the mass balance of each species in each sample across all the samples in the dataset, based on the model contributions estimates by the model. The residuals are scaled by the uncertainty associated with the measurement of the species. Thus, normally distributed residuals that are in a range of ± 3 times the uncertainty of measurements is considered a good representation of the mass balance for that species. Species with many samples outside of the $+3$ to -3 residual range should be further investigated to determine whether the species should be down-weighted or excluded. The graphical screen reporting the residuals can also be sorted by sample number, allowing the user to consider excluding a sample from analysis, should several of the species within that sample not fit well (Norris et al., 2014).

3.7.3.2 Observed/Predicted Scatter Plot and Time Series

Using the observed/predicted scatter plot provides the capability for the user to compare the observed data to the predicted values for each species. Ideally, each species will have a strong correlation, indicating that the input data is aligned with the modeled values. Species with a weak correlation indicates that consideration should be made for down-weighting or excluding the species from analysis (Norris et al., 2014).

The observed/predicted time series allows the user to select species and plot the time series observed/input data over the predicted/modeled data. Peaks on the graph should be reproduced in both of the data series (Norris et al., 2014).

3.7.3.3 *Other Diagnostics*

As mentioned, the nature of the minimum (local or global) is an issue that arises with optimization problems. If the model runs starting from different initial guesses and results in the same minimum, it is confirmed that a global minimum has been reached. PMF allows for this investigation by first conducting the specified number of “Base runs” starting with random starting points for the G and F matrices. Once the model is run with the desired uncertainties and down-weighting, it should be ensured that base runs have all converged. Non-converged runs can be indicative of low uncertainties and poor signal to noise ratios. The Q-values in the base model runs are goodness-of-fit parameters to determine how well the model represents the input data, which is calculated using Equation (5) (a detailed reformulation of Equation (4) in Section 3.7.1) (Norris et al., 2014).

$$Q = \sum_{i=1}^n \sum_{j=1}^m \left[\frac{x_{ij} - \sum_{k=1}^p g_{ik} f_{kj}}{u_{ij}} \right]^2 \quad (5)$$

The model reports two Q values: Q(true), which is calculated with all species and samples, and Q(robust), which is calculated with outliers removed. The outliers here outliers which are poorly modelled and not the outliers identified in the preliminary measured data quality control/assurance procedures. The range of the Q(true) and Q(robust) should be within a few units. Should the range be larger than this, species with low S/N ratios, and those that

were identified as potential outliers during data validation should be excluded or down-weighted. Last, the $Q(\text{true})$ and $Q(\text{robust})$ should be near the calculated Q_{expected} , which is equal to the number of non-weak data values in X minus the number of elements in G and F , taken together (Norris et al., 2008). The profiles/contributions tab in the PMF user interface has an option to observe the Q/Q_{exp} for each species thereby identifying those species that may need to be down-weighted or excluded. The diagnostic base run file also lists the Q/Q_{exp} for each run which can be used to assess the overall fit of the model to the theoretical model. This ratio should ideally fall between 1.5 and 2, where higher values indicate the possibility needing to apply a higher number of factors or exclude or down-weight more species with low S/N ratios.

To support the findings from examining Q/Q_{exp} , the residuals between base runs can be compared by adding the squared difference between the uncertainty-scaled residuals for each pair of base runs as described in Equation 8 where r is the scaled residual, i is the sample, j is the variable, and k and l are two different runs (Norris et al., 2014).

$$d_{jkl} = \sum_i (r_{ijk} - r_{ijl})^2 \quad (6)$$

The diagnostics file reports a matrix of D_{kl} values, which, as shown in Equation 9, is the sum of these squared-difference scaled residuals. Using a combination of the squared-difference scaled residuals matrix and the matrix of D_{kl} -values, large variations would help identify species that do not fit well within the model and also indicate two runs that result in different solutions (Norris et al., 2014).

$$D_{kl} = \sum_j d_{jkl} \quad (7)$$

The diagnostic file also provides regression diagnostics for each of the species based on their fit to predicted values. This is further demonstrated in

Figure 3-3, which shows an example of the observed/predicted scatter plot and the corresponding diagnostics for each species (Norris et al., 2008).

These diagnostics can be used to identify species that may stray from the predicted results. The user may use these additional diagnostics in determining if species are fit to be included in analysis.

Figure 3-3: Example of PMF observed/predicted scatter plot output

Ideal diagnostic values include (Norris et al., 2008):

- Slope near 1;
- Intercept near 0;
- Coefficient of determination (r^2) larger than 0.6; and
- Mean squared error near 0.

3.7.3.4 *Bootstrapping*

The sensitivity of the modeled solution to different segments of the data can be examined by a “bootstrapping” technique once a satisfactory base run is identified. This is done by creating a new input data file with the same dimensions as the original data set but using only a fraction of the original data set: randomly selecting non-overlapping blocks of samples from the original dataset and repeating them to obtain the required dimensions. The block size and number of random non-overlapping blocks that are needed to construct a new dataset are calculated according to Politis and White (2003). The number of bootstraps is recommended to be 100 to ensure robustness, however 20 to 50 runs can be used initially to quickly gauge the stability of the original solution. For each bootstrap run the identified factors are compared with the factors in the “base run” and considered “mapped” to a base run factor if the correlation coefficient between the “bootstrap factor” and the “base factor” is above a pre-set criterion (typically 0.6). Confidence in the reliability (robustness) of the original solution increases as the fraction of “mapped” bootstrap factors increases (e.g. 95%). In carrying out the bootstrapping technique the minimum correlation r-value of 0.6 may be decreased if a large number of factors are unmapped, if the change to the r-value is noted with the final solution (Norris et al., 2014).

4 Sampling Results Analysis

Prior to receptor modelling, descriptive statistics were applied to the 81 relevant species identified in Table 4-2 of Section 4.3 and other subsections. This provided a better understanding of the dataset and how it is distributed.

4.1 Minitab 17 Statistical Software

Analysis of the raw data was conducted using Minitab 17 statistical software. Projects can be created which can store worksheets, graphs, session output and history, settings, layout and options (Minitab Inc., 2014). A new worksheet can be inputted into the program or an existing worksheet such as a Microsoft Excel spreadsheet file can be uploaded. Once data is inputted, the Graph and Stat menus can be used to interpret results. Features from these menus were largely used when interpreting RAGI raw data in the following sections.

4.2 Source Marker Analysis

The samples collected in the Summa canisters were originally analyzed for a suite of 194 species. A source marker analysis of this species suite was conducted through a literature review of work from (Batterman et al., 2006) (Batterman et al., 2007) (Dodson et al., 2008) (Jia et al., 2008a) (Jia et al., 2008b) (Kuntasal, 2005) (Norris et al., 2014) (Sexton, et al., 2004) (Ohura et al., 2009) and (Watson et al., 2004).

The literature typically involved some version of factor analysis and therefore required the use of species markers in the identification of sources. From this, markers applicable to the sources and factor analysis of RAGI data in Ottawa were extracted from the literature and

summarized in Table 4-1. These identified species were then retained for the unique identification of one or two sources. For example, benzene is a well-known fuel marker from both vehicle exhaust and the volatilization of fuel. Ethylbenzene and ethylene are also markers for vehicle exhaust; however, ethylbenzene is a marker for the volatilization of fuel while ethylene is not (Batterman et al., 2006) (Kuntasal, 2005). The comparison of these two species provides insight to how much fuel stored is being volatilized. The comparison of ethylene and acetylene by Doskey, Porter and Scheff determined that ratios larger than 1 were indicative of roadway emissions but less than 1 tended to indicate cold-start emissions (Doskey et al., 1992). Summarizing these source markers, it is possible to apply these species when running a factor analysis to help in the identification of factors. Furthermore, knowing what these source markers are prior to running the PMF analysis ensures that extra care is taken when down-weighting or removing a species from analysis, so as to avoid removing invaluable species which can lead to positive source identification.

Table 4-1: Species Markers for Summa Analysis suite

Species Name	Group	Veh. exhaust	Volat. fuel	volatization - other					Biogenic	Miscellaneous	Microenvironment (Outdoor/Garage/Indoor)	Reference(s)
		Mix / Gas / Diesel	General / Gas / Diesel	Paints/Cleaners/Solvents	Degreasers/Sprays/Lubricants	Furniture/Wood Products	Personal Care Products	Cleaners				
1,1,1-Trichloroethane	haloalkene			x	x						I,G	(Kuntasal, 2005)
1,2,3-Trimethylbenzene	aromatic	mix									O	(Ohura et al., 2009) (Batterman et al., 2006)
1,2,4-Trimethylbenzene	aromatic	mix/gas	mix							Solvent - Printer Ink	O,I	(Kuntasal, 2005)(Ohura et al., 2009)(Batterman et al., 2006)
1,2-Dichlorobenzene	haloaromatic			x						Herbicide	I,G	(Jia et al., 2008b)
1,2-Dichloroethane	haloalkane			x							O,G,I	(Jia et al., 2008b)
1,3,5-Trimethylbenzene	aromatic	mix									O	(Kuntasal, 2005) (Ohura et al., 2009) (Batterman et al., 2006)
1,3-Butadiene	alkene	mix									O	(Ohura et al., 2009)
1,3-Dichlorobenzene	haloaromatic			x							I,G	
1,4-Dichlorobenzene	haloaromatic			x						Mothballs	I,G	(New York Department of Health, 2013)
1-Butene/ 2-Methylpropene	alkene	mix/gas									O	Gasoline (Jenna Templar, 2005): if more of these, exhaust; if less, liquid fuel evap.
1-Methylcyclohexene	cycloalkene	gas									O	(Batterman et al., 2006)
1-Pentene	alkene	gas									O	Gasoline (Jenna Templar, 2005):
2,2-Dimethylbutane	alkane	diesel	gas								O,G	Diesel exhaust (Jenna Templar, 2005). (Batterman et al., 2006)
2,3-Dimethylbutane	alkane		gas								O,G	(Batterman et al., 2006)

2-Methylbutane	alkane	gas										O	(Kuntasal, 2005)
2-Methylhexane	alkane	gas										O	Gas exhaust (Jenna Templar, 2005).
3-Ethyltoluene	aromatic	mix										O	(Kuntasal, 2005)
4-Ethyltoluene	aromatic	gas										O	(Batterman et al., 2006)
a-Pinene	monoterpene							x	X	Cleaner (Pine smell)	I,G,O		Biogenic (Jenna Templar, 2005). (Batterman et al., 2006)
Acetaldehyde	aldehyde					x						I	
Acetone	ketone			x				x		Industrial Solvent / Personal Care Products	I		(New York Department of Health, 2013)
Acetylene	alkyne	mix/gas	gas									O,G	(Kuntasal, 2005) Gasoline exhaust (Jenna Templar, 2005). Traffic exhaust (US EPA, 2008).
Acrolein (2-Propenal)	aldehyde									Gas Stove	I		
b-Pinene	monoterpene							x	X	Cleaner (Pine smell)	I,G,O		Biogenic (Jenna Templar, 2005). (Batterman et al., 2006)
Benzaldehyde	aromatic								x	Toluene Oxidation	O		(Edwards et al., 2001)
Benzene	aromatic	mix/gas	mix							BTEX	O,G		(Watson et al., 2004) (Norris et al., 2014) (Batterman et al., 2006)
Butane	alkane			x								O,G,I	(Norris et al., 2014)
Camphene	monoterpene							x		Cleaner	I,G,O		(Batterman et al., 2006)
Carbon tetrachloride	haloalkane									Solvents / Propellants	O		(Kuntasal, 2005) (Batterman et al., 2006)
Chloroform	haloalkane			x				x		Water Treatment (Chlorine)	O,I		(Kuntasal, 2005) (Batterman et al., 2006)
Cyclohexane	cycloalkane		mix									O,G	(Batterman et al., 2006)
Decane	alkane	diesel	mix	x								O,G,I	Diesel exhaust or paints/solvents (Jenna Templar, 2005). (Norris et al., 2014) (Batterman et al., 2006)
Dibromochloromethane	haloalkane											O,I	(Jia et al., 2008b)
Dichloromethane	haloalkane				x	x						G,I	
Dodecane	alkane	diesel	mix	x	x							O,G	Diesel exhaust or paints/solvents (Jenna Templar, 2005). (Norris et al., 2014) (Batterman et al., 2006) (Batterman et al., 2007)

Ethane	alkane	gas	mix							LPG vehicle, petrochem. refining/ natural gas, "aged air"	O,G	(Kuntasal, 2005) Gas (Jenna Templar, 2005). (Norris, Duvall, Brown, & Bai, 2014)
Ethanol	alcohol						x				I	
Ethylacetate	ester						x				I	(Jia et al., 2008b)
Ethylbenzene	aromatic	mix/gas	mix							BTEX	O,G	(Batterman et al., 2006)
Ethylene	alkene	mix/gas								LPG Vehicle, Petrochem. Industry	O,G	(Kuntasal, 2005) (Doskey et al., 1992)(Norris et al., 2014)
Freon 11	HCFC									Solvent - Refrigerant	O	(Kuntasal, 2005)
Freon 113	HCFC									Solvent - Refrigerant	O	(Kuntasal, 2005)
Freon 114	HCFC									Solvent - Refrigerant	O	(Kuntasal, 2005)
Freon 12	HCFC									Solvent - Refrigerant	O	(Kuntasal, 2005)
Freon 134A	HCFC									Solvent - Refrigerant	O	(Kuntasal, 2005)
Freon 22	HCFC									Solvent - Refrigerant	O	(Kuntasal, 2005)
Heptane	alkane	gas	gas								O,G	(Batterman et al., 2006) (Batterman et al., 2007)
Hexadecane	alkane	diesel		x	x						O,G,I	Diesel exhaust or paints/solvents (Jenna Templar, 2005). (Norris et al., 2014) (Batterman et al., 2006) (Batterman et al., 2007)
Hexane	alkane	mix/gas	mix			x					G,O,I	Gas exhaust (Jenna Templar, 2005).
Isobutane	alkane	mix	gas								O,G	Gas evap (Jenna Templar, 2005); (Batterman et al., 2006)
Isoprene	alkene	mix		x					x		O,G,I	(Kuntasal, 2005) (Watson et al., 2004) (Norris et al., 2014)
Isopropyl Alcohol	alcohol						x				I	(New York Department of Health, 2013)
Limonene	cyclic terpene							x		cleaner (citrus smell)	I,G	(Batterman et al., 2006)

m-, p-Xylene	aromatic	mix/gas	mix		x	x				BTEX	O,G,I	(Kuntasal, 2005)(Batterman et al., 2007) (Watson et al., 2004)
MEK (2-Butanone)	ketone				x						G	
Methyl-t-Butyl Ether	ether	gas	gas							Additive	O,G	(Watson et al., 2004)
MIBK	ketone			x							O,G	(Jia et al., 2008b)
Naphthalene	PAH	gas								Combustion (Outdoors), Mothballs	O,G,I	(Kuntasal, 2005) (Batterman et al., 2006) (Batterman et al., 2007)
Nonane	alkane		gas								G,O	(Batterman et al., 2007)
o-Xylene	aromatic	mix/gas	mix		x	x				BTEX	O,G,I	(Norris et al., 2014) (Batterman et al., 2006)
Octane	alkane	gas	gas								G,O	(Batterman et al., 2006) (Batterman et al., 2007)
p-Cymene	aromatic	gas									O	(Batterman et al., 2006)
Pentadecane	alkane	diesel		x	x						O,G,I	Diesel exhaust or paints/solvents (Jenna Templar, 2005). (Norris et al., 2014) (Batterman et al., 2006) (Batterman et al., 2007)
Pentane	alkane	mix	gas	x							O,G	(Kuntasal, 2005) (Norris et al., 2014)(Batterman et al., 2006)
Propane	alkane	diesel								Barbeque, LPG vehicle, Natural Gas / "aged air"	O,G	(Kuntasal, 2005) Diesel (Jenna Templar, 2005). (Norris et al., 2014)
Propene	alkene	diesel								Petrochem. Industry, Natural Gas	O,G	Diesel vehicle exhaust (Jenna Templar, 2005). (Norris et al., 2014)
Styrene	aromatic			x		x				Solvent - Printer Ink	I	(Kuntasal, 2005) Solvents (Jenna Templar, 2005). (Norris et al., 2014) (Batterman et al., 2007)
t-2-Butene	alkene		gas								O,G	(Batterman et al., 2006)
t-2-Pentene	alkene		gas								O,G	(Batterman et al., 2006)
Tetrachloroethene	haloalkene				x						G	(New York Department of Health, 2013)
Tetradecane	alkane	diesel		x	x						O,G,I	Diesel exhaust or paints/solvents (Jenna Templar, 2005). (Norris et al., 2014)(Batterman et al., 2006) (Batterman et al., 2007)

4.3 Species Screening

Original analysis of the Summa samples yielded results for 194 species. Many of these species were present at levels below laboratory detection limits. Furthermore, attempting receptor modelling on a species suite as large as the original suite would be ineffective for interpretation and would likely result in a non-robust solution. Species were thus screened out from further analysis based on the following exclusion criteria:

- Percentage of species data below detection limit. If more than 50% of the number of samples for a species were below detection limit, the species was excluded from analysis; if 50% or more of the samples were above detection limit, the species was retained for analysis
- Signal-to-noise (S/N) ratio. If a species had a signal-to-noise ratio of less than 1, the species was excluded from analysis; if a species had a signal-to-noise ratio of between 1.5 to 2, it was “maybe” considered; if a species had a signal-to-noise ratio of more than 2 it was retained for analysis
- Marker species: those species identified in Section 4.2 as marker species were retained for analysis, regardless of the above mentioned screening criteria.

The PMF Baton Rouge Case Study published by the U.S. EPA used a guideline where if 50% of the samples for a species are below the detection limit, it renders species samples unusable (U.S. Environmental Protection Agency, 2008). Bari et. al (2015) used an even more aggressive requirement that 80% of the samples for a species must be above the method detection limit to be selected for consideration in the model.

The signal-to-noise ratio was determined using PMF diagnostics and indicates whether the variability in the measurements is real or within the noise of the data. This is done in PMF through two calculations (Norris et al., 2014). First, the difference between the concentration (x_{ij}) of species j in sample i and uncertainty (s_{ij}) of species j in sample i is calculated for those samples where the concentration value exceeds the uncertainty as in Equation (8):

$$d_{ij} = \left(\frac{x_{ij} - s_{ij}}{s_{ij}} \right) \quad (8)$$

if

$$x_{ij} > s_{ij}$$

Then, the S/N ratio for species j is calculated as:

$$\left(\frac{S}{N} \right)_j = \frac{1}{n} \sum_{i=1}^n d_{ij} \quad (9)$$

Inclusion based on S/N ratio varies amongst literature, the U.S. EPA states that a very conservative approach to categorize species is to categorize S/N below 0.5 as “bad”, and S/N more than 0.5 but less than 1 as “weak” (Norris et al., 2014). McCarthy et al. (2013) applied a stricter approach, where an S/N ratio greater than 2.5 was required for inclusion in the analysis and therefore anything lower resulted in a “bad” categorization. Paatero and Hopke use an S/N between 0.2 and 2 to define variables as weak and less than 0.2 to be defined as bad. This is prefaced by the idea that the definition is dependent on the representation of the concentrations (Paatero & Hopke, 2003).

The third screening criterion allowed species to be retained if it was considered a valuable marker, regardless of the first two screening criteria. Most of the species that had a “maybe” consideration using the S/N criterion had a percentage of samples below detection limit greater than 50 and were thus excluded. However, those species that satisfied the % BDL criterion and were categorized as a “maybe” under the S/N criterion were retained if the species was a marker. This screening protocol resulted in a more manageable suite of 81 species as listed in Table 4-2.

Table 4-2: List of 81 VOCs to be input into PMF post-screening

ID	Species Name	Group	MW	Percent Abundance, Median		
				Outdoor	Indoor	Garage
S001	Acetylene	alkyne	26.0	0.9%	0.1%	0.2%
S002	Ethylene	alkene	28.1	1.3%	0.2%	0.5%
S003	Ethane	alkane	30.1	4.7%	0.7%	0.5%
S004	Methanol	alcohol	32.0	19.2%	11.8%	18.7%
S006	Acetonitrile	nitrile	41.1	0.2%	0.0%	0.2%
S007	Propene	alkene	42.1	0.4%	0.0%	0.2%
S008	Acetaldehyde	aldehyde	44.1	9.0%	1.8%	1.2%
S010	Propane	alkane	44.1	4.4%	0.9%	0.6%
S011	Ethanol	alcohol	46.1	4.7%	45.2%	10.2%
S012	Chloromethane	haloalkane	50.5	1.7%	0.1%	0.1%
S015	1,3-Butadiene	alkene	54.1	0.0%	0.0%	0.0%
S016	Acrolein	aldehyde	56.1	4.0%	0.7%	0.4%
S017	1-Butene	alkene	56.1	0.3%	0.1%	0.4%
S019	t-2-Butene	alkene	56.1	0.1%	0.1%	0.5%
S020	Acetone	ketone	58.1	7.6%	2.9%	1.2%
S023	Butane	alkane	58.1	3.1%	1.4%	5.0%
S024	Isobutane	alkane	58.1	1.5%	1.2%	1.6%
S025	Isopropyl Alcohol	alcohol	60.1	0.0%	0.2%	0.0%
S030	Isoprene	alkene	68.1	0.0%	0.2%	0.0%
S033	1-Pentene	alkene	70.1	0.1%	0.0%	0.2%
S035	t-2-Pentene	alkene	70.1	0.1%	0.1%	0.8%
S042	MEK (2-Butanone)	ketone	72.1	1.3%	0.2%	0.2%
S044	2-Methylbutane	alkane	72.2	0.0%	0.0%	0.0%
S045	Pentane	alkane	72.2	1.0%	0.4%	3.1%
S046	Methyl Acetate	ester	74.1	0.2%	0.1%	0.0%

S050	Carbon Disulfide	sulfide	76.1	0.1%	0.0%	0.0%
S051	Benzene	aromatic	78.1	0.8%	0.1%	0.7%
S063	Cyclohexane	cycloalkane	84.2	0.1%	0.0%	0.2%
S069	Dichloromethane	haloalkane	84.9	0.5%	0.1%	0.1%
S073	2,2-Dimethylbutane	alkane	86.2	0.1%	0.0%	0.2%
S074	2,3-Dimethylbutane	alkane	86.2	0.1%	0.0%	0.4%
S075	2-Methylpentane	alkane	86.2	0.6%	0.1%	0.1%
S077	Hexane	alkane	86.2	0.4%	0.2%	1.2%
S078	Freon 22	HCFC	86.5	1.0%	0.1%	0.1%
S079	Ethylacetate	ester	88.1	0.1%	0.4%	0.0%
S080	Methyl t-Butyl Ether	ether	88.2	0.0%	0.0%	0.0%
S083	Toluene	aromatic	92.1	1.0%	0.8%	4.4%
S093	Methylcyclohexane	alicyclic hydrocarbon	98.2	0.1%	0.1%	0.2%
S097	1,2-Dichloroethane	haloalkane	99.0	0.1%	0.0%	0.0%
S099	MIBK	ketone	100.2	0.0%	0.0%	0.1%
S104	2-Methylhexane	alkane	100.2	0.4%	0.2%	1.8%
S105	3-Methylhexane	alkane	100.2	0.3%	0.1%	0.6%
S106	Heptane	alkane	100.2	0.2%	0.1%	0.5%
S108	Freon 134A	HCFC	102.0	0.6%	0.1%	0.2%
S110	Styrene	aromatic	104.2	0.0%	0.0%	0.0%
S111	Benzaldehyde	aromatic	106.1	0.3%	0.1%	0.0%
S112	Ethylbenzene	aromatic	106.2	0.2%	0.1%	0.6%
S113	m-, p-Xylene	aromatic	106.2	0.4%	0.3%	1.9%
S114	o-Xylene	aromatic	106.2	0.2%	0.1%	0.7%
S124	1-Octene	alkene	112.2	0.0%	0.0%	0.0%
S133	2-Methylheptane	alkane	114.2	0.2%	0.1%	0.6%
S136	Octane	alkane	114.2	0.1%	0.0%	0.2%
S137	Butylacetate	ester	116.2	0.0%	0.1%	0.0%
S140	Chloroform	haloalkane	119.4	0.1%	0.1%	0.0%
S141	1,2,3-Trimethylbenzene	aromatic	120.2	0.0%	0.0%	0.1%
S142	1,2,4-Trimethylbenzene	aromatic	120.2	0.2%	0.2%	0.8%
S143	1,3,5-Trimethylbenzene	aromatic	120.2	0.0%	0.0%	0.2%
S145	3-Ethyltoluene	aromatic	120.2	0.1%	0.1%	0.5%
S146	4-Ethyltoluene	aromatic	120.2	0.1%	0.0%	0.3%
S149	Freon 12	HCFC	120.9	3.3%	0.2%	0.2%
S154	Naphthalene	PAH	128.2	0.1%	0.0%	0.1%
S155	Nonane	alkane	128.3	0.1%	0.1%	0.1%
S156	Trichloroethene	haloalkene	131.4	0.0%	0.0%	0.0%
S157	1,1,1-Trichloroethane	haloalkene	133.4	0.0%	0.0%	0.0%
S165	p-Cymene	aromatic	134.2	0.0%	0.1%	0.0%
S168	a-Pinene	monoterpene	136.2	0.0%	0.3%	0.0%
S169	b-Pinene	monoterpene	136.2	0.0%	0.0%	0.0%
S170	Limonene	cyclic terpene	136.2	0.0%	0.6%	0.0%

S171	Camphene	monoterpene	136.2	0.1%	0.0%	0.0%
S172	Freon 11	HCFC	137.4	2.0%	0.1%	0.1%
S176	Decane	alkane	142.3	0.1%	0.1%	0.1%
S177	1,2-Dichlorobenzene	haloaromatic	147.0	0.0%	0.0%	0.0%
S178	1,3-Dichlorobenzene	haloaromatic	147.0	0.0%	0.0%	0.0%
S179	1,4-Dichlorobenzene	haloaromatic	147.0	0.0%	0.0%	0.0%
S180	Carbon tetrachloride	haloalkane	153.8	0.6%	0.0%	0.0%
S183	Undecane	alkane	156.3	0.1%	0.1%	0.1%
S186	Tetrachloroethene	haloalkene	165.8	0.1%	0.0%	0.0%
S188	Dodecane	alkane	170.3	0.1%	0.1%	0.0%
S189	Freon 114	HCFC	170.9	0.1%	0.0%	0.0%
S193	Freon 113	HCFC	187.4	0.7%	0.0%	0.0%
S197	Dibromochloromethane	haloalkane	208.3	0.0%	0.0%	0.0%

The species list is sorted by species ID, which was labelled in order of increasing molecular weight. The median percent abundance for each of the species in the three types of samples is listed in the last three columns.

4.4 Summation Variables

Several groups of summation variables were established to compare results amongst subsections of the species suite. These variables encompassed:

- TVOC - included the entire 194 species that were analyzed;
- SUM81VOC - 81 species that remained following the application of the screening criteria;
- SUM15CEPA - 15 species identified under the toxic substances list published under the *Canadian Environmental Protection Act*, 1999 (CEPA 1999); this list is provided in Table 4-3.
- BTEX – includes the four species that are commonly used as markers for gasoline, which includes benzene, toluene, ethylbenzene and m-, o-, and p-xylenes.

Table 4-3: Summary of SUM15CEPA species

Species ID	VOC
S008	Acetaldehyde
S009	Ethylene oxide
S013	Acrylonitrile (2_Propennitrile)
S015	1_3_Butadiene
S016	Acrolein (2_Propenal)
S027	Vinylchloride (Chloroethene)
S030	Isoprene (2_Methyl_1_3_Butadiene)
S042	MEK (2-Butanone)
S051	Benzene
S069	Dichloromethane
S097	1_2_Dichloroethane
S154	Naphthalene
S157	1_1_1_Trichloroethane
S180	Carbon tetrachloride
S201	Hexachlorobutadiene

The same statistical analysis was applied for each VOC summation variable as well as to each of the top 10 contributing species in each microenvironment.

4.4.1 Percent Abundance

Due to the large number of species analyzed, considering those species of highest abundance was useful to reduce the number of significant contributors. Furthermore, the extent which the summation variables identified in Section 4.4 contribute to the total concentration can be identified, thereby increased or decreasing the importance of that variable.

It was determined that the most abundant species were not consistent across microenvironments, which was expected as different source types are present in each microenvironment. Table 4-4 summarizes the top ten species for each microenvironment sampled.

Table 4-4: Top ten contributing species for each microenvironment

	Species	Group	MW (g/mol)	Abundance (median)
Outdoor	Methanol	alcohol	32.0	19%
	Acetaldehyde	aldehyde	44.1	9%
	Acetone	ketone	58.1	8%
	Ethane	alkane	30.1	5%
	Ethanol	alcohol	46.1	5%
	Propane	alkane	44.1	4%
	Acrolein (2-Propenal)	aldehyde	56.1	4%
	Freon 12	hydrochlorofluorocarbon	120.9	3%
	Butane	alkane	58.1	3%
	Freon 11	hydrochlorofluorocarbon	137.4	2%
Indoor	Ethanol	alcohol	46.1	45%
	Methanol	alcohol	32.0	12%
	Acetone	ketone	58.1	3%
	Acetaldehyde	aldehyde	44.1	2%
	Butane	alkane	58.1	1%
	Isobutane (2-Methylpropane)	alkane	58.1	1%
	Propane	alkane	44.1	1%
	Toluene	aromatic	92.1	1%
	Ethane	alkane	30.1	1%
	Acrolein (2-Propenal)	aldehyde	56.1	1%
Garage	Methanol	alcohol	32.0	19%
	Ethanol	alcohol	46.1	10%
	Butane	alkane	58.1	5%
	Toluene	aromatic	92.1	4%
	Pentane	alkane	72.2	3%
	m-, p-xylene	aromatic	106.2	2%
	2-Methylhexane	alkane	100.2	2%
	Isobutane (2-Methylpropane)	alkane	58.1	2%
	Hexane	alkane	86.2	1%
	Acetaldehyde	aldehyde	44.1	1%

The top ten species for the outdoor microenvironment contained some expected species such as Freon 11 and Freon 12, which are known to be persistent compounds within the atmosphere. Oddly however, there is an absence of BTEX or other species that represent

gasoline volatilization or traffic exhaust in the top ten contributors, which was unexpected considering the potential for contributions from nearby traffic sources.

Of all microenvironments, Ethanol was most abundant in the indoor microenvironment, contributing 45% of indoor TVOC. Approximately 60% of TVOC indoors are considered alcohols, indicative of indoor sources such as personal care products and solvents (Bari et al., 2015).

The top ten garage microenvironment species were more similar to those indoors than outdoors, which is indicative of similar sources between microenvironments and higher air exchange rates between the home and garage, than the garage and outdoors. Again, methanol and ethanol are the top two contributing species, but only contribute to approximately 30% of the TVOC. Expectedly, the presence of higher levels of BTEX compounds is indicative of vehicle and fuel sources. Table 4-5 presents the percent of concentration that the summation variables contribute to the TVOC.

Table 4-5: Concentration percentage of summation variable contributions to the TVOC

Microenvironment	SUM81 / TVOC	BTEX / TVOC	SUM15CEPA / TVOC
Outdoors, median	90%	3%	18%
Indoors, median	96%	2%	4%
Garage, median	85%	9%	3%

SUM81 captures approximately 90% of the TVOC for outdoor and indoor microenvironments and approximately 85% of TVOC in garages. These values confirm that although the screening procedure resulted in a considerably smaller suite of species, the suite is reasonably representative of the TVOC sampled.

The BTEX summation variable considers a substantially smaller percentage of TVOC in the outdoor and indoor microenvironments than that found in the garage. This is consistent with the fuel-related sources found within the garage microenvironment.

The contribution of SUM15CEPA to TVOC is much greater in the outdoor microenvironment, contributing to approximately 20% of the TVOC whereas it contributes less than 5% to indoor and garage microenvironments. This is due to the presence of acetaldehyde and acrolein in the SUM15CEPA variable, which are common markers for volatilization of furniture/wood products and gas stoves, respectively and incomplete combustion of mobile sources, agricultural burning and wildfires (Meininghaus, Gonzalez-Flesca, Cicoella, & Bastin, 2001).

4.5 Descriptive Statistics

4.5.1 Summation Variables

The results of the descriptive statistics work using the summation variables described in Section 4.4 are summarized in Table 4-6 below. All four summation variables for each microenvironment were analyzed for the mean, standard deviation (SD), coefficient of variation (CV), minimum, first quartile (Q1), median, third quartile (Q3), maximum, range, interquartile range (IQR), skewness and kurtosis.

Typically, TVOC and SUM81 results were similar since the species removed to form SUM81 contributed very little to the overall concentrations in TVOC. The median was highest indoors and the indoor and garage medians were 2 orders of magnitude higher than the outdoor median, as expected due to the diluted nature of ambient air. The median for BTEX followed a similar trend in that the indoor and garage medians were a magnitude

higher than the outdoor median. This trend did not remain true for SUM15CEPA where the median remained within the same magnitude across microenvironments, with the indoor median greater than garage and the garage greater than outdoor. The difference in median values amongst microenvironments solidifies the reasoning for conducting the RAGI study, where VOC concentrations are found to be highest indoors in homes with attached garages (Dodson et al., 2008).

Table 4-6: Descriptive Statistics for Summation Variables

	Environ.	Count	Mean ($\mu\text{g}/\text{m}^3$)	SD ($\mu\text{g}/\text{m}^3$)	CV ($\mu\text{g}/\text{m}^3$)	Min. ($\mu\text{g}/\text{m}^3$)	Q1 ($\mu\text{g}/\text{m}^3$)	Median ($\mu\text{g}/\text{m}^3$)	Q3 ($\mu\text{g}/\text{m}^3$)	Maximum ($\mu\text{g}/\text{m}^3$)	Range ($\mu\text{g}/\text{m}^3$)	IQR ($\mu\text{g}/\text{m}^3$)	Skewness	Kurtosis
SUM81	Garage	99	2394	4009	167.48	172	526	1126	2633	29419	29247	2107	4.48	24.84
	Indoors	100	1922	1208	62.85	161	975	1607	2708	4909	4748	1733	0.73	-0.36
	Outdoors	103	81.99	46.04	56.16	30.36	50.82	70.66	103.82	363.28	332.92	53.00	2.76	13
TVOC	Garage	99	2724	4335	159.15	195	626	1288	3050	30075	29880	2424	4.14	20.87
	Indoors	100	2025	1314	64.89	173	1026	1685	2827	5997	5825	1801	0.98	0.51
	Outdoors	103	91.3	53.42	58.51	34.62	57.44	78.07	117.98	458.68	424.06	60.55	3.59	21.26
BTEX	Garage	99	183.2	213.5	116.52	2.5	34.3	84.2	234.7	1094	1091.5	200.4	1.92	3.89
	Indoors	100	76.1	237.8	312.68	4.5	11.9	23	52.6	1581.8	1577.3	40.6	5.54	30.12
	Outdoors	103	2.377	1.353	56.92	0.680	1.348	1.888	3.212	6.076	5.396	1.864	1.01	0.05
SUM15CEPA	Garage	99	60.36	74.93	124.13	10.05	23.48	42.9	63.63	579.79	569.74	40.15	4.32	24.44
	Indoors	100	83.4	77.99	93.52	14.72	40.65	63.83	105.33	632.88	618.16	64.68	4.2	25.25
	Outdoors	103	17.44	22.08	126.58	5.40	10.08	12.7	17.01	205.48	200.08	6.93	6.71	53.23

The coefficient of variation is a value that indicates the amount of variability with respect to the mean. It can be used instead of standard deviation to compare data sets that have different units or means (Minitab Inc., 2015). The CV for TVOC and SUM81 indicates that there is 1.5 times more variation amongst samples from the garage than indoors or outside. BTEX, however, varies a significant amount (6 times more) indoors than outdoors and 2.5 times more than in the garage. This is consistent with what the BTEX summation variable represents, since BTEX is indicative of gasoline or traffic sources and the extent of infiltration into the indoors microenvironment will vary greatly dependent upon the seal of the home and the extent to which air from outdoor or garage sources can permeate. Hypothetically, newer or upgraded homes will have a much lower BTEX concentration, compared to those older homes with a poor seal. This variability in concentration amongst samples and homes leads to this higher CV for the indoor microenvironment. The CV for SUM15CEPA is more consistent amongst microenvironments, which is expected since the highest concentrations of SUM15CEPA species are noticed outdoors and therefore should not vary much amongst homes within Ottawa.

Skewness is a measure of how unsymmetrical the data set is. A symmetrical distribution is represented by a skewness value of zero. A lack of skewness however, does not imply normality. A positive value indicates a right skewed distribution indicates that the tail of the distribution is on the right side and a negative value for skewness indicates a tail pointing towards the left (Minitab Inc., 2015). Kurtosis is another statistical indicator that is often coupled with skewness to identify the distribution of a data set. A kurtosis value of zero indicates that the data follows a normal distribution, perfectly. A positive kurtosis value indicates the tails of the distribution are heavier weighted with a sharper peak. An

example of a positive kurtosis is data with a t-distribution. Contrarily, a negative kurtosis indicates that the peak is less sharp and the tails of the data distribution are less prominent (Minitab Inc., 2015). The TVOC and SUM81 variables show that the garage distribution is highest peaked with the indoor concentrations approaching a relatively normal distribution. These distributions across all microenvironments exhibit a right skew indicating that most concentrations within the dataset tend to be lower, with a few high concentrations contributing to a higher mean than median. Unlike TVOC and SUM81, the distribution for indoor concentrations of BTEX is very peaked and right-skewed. In this case, it is the outdoor microenvironment where BTEX is close to normally distributed. This could from a few high BTEX events occurring within in garages and therefore migrating to and reading in the home. These events would have little to no effect on the ambient outdoor concentrations and therefore, readings would be more consistent and closer to a normal distribution. The SUM15CEPA variable in all three microenvironments has high peaks that are right skewed. Overall, this evaluation indicates that the variables are consistently right skewed, but seem to be largely log-normally distributed, therefore indicating the use of non-parametric tests for statistical analysis (Minitab Inc., 2015).

4.5.2 Individual Species

The same analysis was applied for the all of the species in each microenvironment as well as the top ten contributing species determined by median concentration. The summary statistics for all species in each microenvironment are provided in Appendix C. The summary statistics for the top ten species, listed in order of abundance, are shown in Table 4-7.

Within the indoor microenvironment, the top three contributing species are ethanol, methanol and acetone. The ethanol interquartile range is much higher, by one order of magnitude against almost all of the other species. Furthermore, ethanol and methanol maximums are more than five times those of other species. Ethanol can be found in personal care products and is a common solvent in household cleaning agents like bleach, detergents, disinfectants and cleaners (Bari et al., 2015). All of the species in the indoor environment have a right-skewed distribution indicative of a higher count of low concentration readings. Ethanol is one of the top ten species though that has a relatively normal distribution, whereas the remaining species are an order of a magnitude higher with a higher peaked distribution.

Similarly, the top three contributors to the garage microenvironment are methanol, ethanol and butane. In this case, the methanol interquartile range is approximately five times as great as ethanol with a maximum that is twelve times as much as butane. Each of the species in the garage microenvironment is right-skewed and has a higher peaked distribution than normal distribution.

Last, the outdoor microenvironment is most affected by methanol, acetaldehyde and acetone. These species are predictably different from those in the indoor and garage microenvironments, which were expected to have considerable overlap. Many of the species in the outdoor microenvironment, including ethane, propane and Freon 11 and 12, approach normal distribution. Furthermore, the maximums and the interquartile ranges for the species are significantly lower as expected for the outdoor microenvironment.

Table 4-7: Summary Statistics for Top 10 Contributing Species

	Variable	Count	Mean ($\mu\text{g}/\text{m}^3$)	SD ($\mu\text{g}/\text{m}^3$)	CV ($\mu\text{g}/\text{m}^3$)	Min. ($\mu\text{g}/\text{m}^3$)	Q1 ($\mu\text{g}/\text{m}^3$)	Median ($\mu\text{g}/\text{m}^3$)	Q3 ($\mu\text{g}/\text{m}^3$)	Max. ($\mu\text{g}/\text{m}^3$)	Range ($\mu\text{g}/\text{m}^3$)	IQR ($\mu\text{g}/\text{m}^3$)	Skew	Kurtosis
Indoor	Ethanol	100	945.5	779.2	82.41	39.8	378.1	622.9	1251.5	3242.5	3202.7	873.4	1.14	0.37
	Methanol	100	308.2	459	148.94	43.1	115.5	170.1	267.5	3736.3	3693.2	152	5	32.34
	Acetone	100	63.82	66.27	103.84	10.52	31.46	42.7	70.16	496.42	485.9	38.7	4.06	21.17
	Acetaldehyde	100	43.1	66.94	155.31	4.85	18.78	25.96	44.42	596.56	591.71	25.64	6.37	48.91
	Butane	100	53.4	109.5	205.18	2.8	8.8	15.6	40.4	591.2	588.4	31.6	3.55	12.9
	Isobutane	100	53.1	103.2	194.43	1.7	6.5	15.6	48.2	665.5	663.8	41.7	3.64	15.02
	Propane	100	25.58	39.66	155.05	3.62	7.48	9.94	26.5	222.43	218.81	19.03	3.28	11.31
	Toluene	100	27.73	57.96	209.01	2.04	6.15	11.88	25.49	359.45	357.42	19.34	4.85	24.13
	Ethane	100	20.29	27.1	133.56	4.13	7.96	12.13	17.75	132.25	128.11	9.79	3.16	9.39
	Acrolein	100	12.53	12.86	102.63	1.46	6.41	9.59	14.81	100.8	99.34	8.41	4.68	27.38
Garage	Methanol	99	1309	3398	259.59	0	78	206	886	27064	27064	808	5.4	35.71
	Ethanol	99	199.7	236.3	118.32	22.4	65.3	115.8	212.1	1351	1328.6	146.8	2.68	8.08
	Butane	99	164.6	341	207.2	2.4	22.6	55	152.1	2156.1	2153.7	129.5	4.25	19.46
	Toluene	99	94.6	109.3	115.56	1.2	19.5	49.3	116.1	418.4	417.2	96.7	1.62	1.73
	Pentane	99	80.5	137.1	170.34	0.7	10.7	34.7	78.9	700.7	700	68.3	3.26	10.94
	m-, p-Xylene	99	45.64	62.68	137.33	0.34	7.35	19.81	53.27	385.28	384.94	45.92	2.73	9.42
	2-Methylhexane	99	42.24	67.15	158.97	0.21	6.93	20.94	49.94	377.89	377.69	43.02	3.36	12.29
	Isobutane	99	61.4	116.3	189.33	1.2	8.4	23.9	53.9	728.5	727.3	45.5	4.16	19.74
	Hexane	99	29.51	41.09	139.25	0.21	5.4	15.4	33.39	212.93	212.72	27.99	2.69	7.97
	Acetaldehyde	99	25.93	49.05	189.14	3.59	7.94	11.84	25.32	413.25	409.66	17.38	5.89	41.56

Outdoors	Methanol	103	22.21	21.46	96.63	0	6.6	13.05	36.94	93.09	93.09	30.34	1.46	1.71
	Acetaldehyde	103	8.96	10.68	119.16	2.66	4.39	6.7	9.58	99.5	96.84	5.19	6.51	51.75
	Acetone	103	7.467	6.633	88.83	2.408	4.78	6.136	8.192	63.932	61.524	3.412	6.5	52.47
	Ethane	103	3.939	1.279	32.47	1.571	2.947	3.776	4.623	7.709	6.138	1.675	0.67	0.09
	Ethanol	103	4.831	4.015	83.11	0.34	2.144	3.884	6.532	27.816	27.476	4.388	2.95	13.36
	Propane	103	3.647	1.175	32.21	1.795	2.805	3.324	4.403	6.857	5.062	1.598	1.02	0.11
	Acrolein	103	4.905	7.63	155.54	0.764	2.056	3.1	4.996	64.344	63.58	2.94	5.71	38.76
	Freon 12	103	2.5594	0.1148	4.49	2.272	2.48	2.552	2.636	2.84	0.568	0.156	0.11	-0.06
	Butane	103	2.968	2.06	69.41	1.056	1.628	2.08	3.888	14.072	13.016	2.26	2.46	8.65
	Freon 11	103	1.5651	0.0802	5.13	1.316	1.516	1.572	1.608	1.748	0.432	0.092	-0.46	0.57

4.5.3 Comparison of Summary Statistics to Literature

The summary statistics for each microenvironment listed were consolidated and compared to literature summary statistics for the 81-species suite that were common amongst both studies. This was done for the Canadian studies since the Canadian studies analyzed were those conducted with Health Canada, therefore providing a similar suite of species to compare. This table is listed in Appendix D: Comparison of Summary Statistics amongst Canadian Studies. Studies in the United States were also considered, however these were unable to be compared interchangeably, considering the different species suite analyzed for in each study. These considered studies were those conducted by Dodson et al. (2008), Batterman et al. (2007) and Jia et al. (2008). Furthermore, a study in Helsinki, Finland, conducted by Edwards et al. was also considered (Edwards et al., 2001). These results are summarized in Appendix E. Table 4-8 below summarizes the study titles, locations, seasons and other relevant details pertaining to the research. If a study provided separate results for winter and summer months, the summer data was removed from consideration to become comparable with the sampling season for RAGI. Unfortunately, due to the lack of garage infiltration studies, there are limited resources available to compare all three microenvironments using the same study.

The Edmonton, Windsor and Regina studies were useful for comparison since each study had some collaboration with or was led by Health Canada, similarly to the RAGI study, and therefore the same sampling methodologies would have been used. These studies however, had only included measurements of VOC indoors and outdoors microenvironments in the scope of the projects and garage sampling was not considered.

Table 4-8: Summary of Study Characteristics for Comparison of Summary Statistics

Country	Author	Study Title	Location	Season	Other Details
Canada	(Bari, Kindzierski, Wheeler, Heroux, & Wallace, 2015)	Source apportionment of indoor and outdoor VOCs at homes in Edmonton, Canada	Edmonton, Canada	Winter; Summer removed	Winter data only; 193 VOCs
	(Health Canada, 2006)	Windsor Exposure Assessment Study (2005-2006): Data Summary for VOC Sampling	Windsor, Canada	Winter; Summer removed	100 study participants; 188 VOCs; winter data only
	(Health Canada, 2007)	Regina Indoor Air Quality Study (2007): Data Summary for VOC Sampling	Regina, Canada	Winter; Summer removed	146 homes; 194 VOCs; 24 hour samples (5 day samples not considered in this comparison)
United States	(Dodson, Levy, Spengler, Shine, & Bennett, 2008)	Influence of basements, garages and common hallways on indoor residential VOC concentrations	Boston, USA	Averaged over Summer and Winter	55 residences; 11 with attached garages
	(Batterman, Hatzivasilis, & Jia, 2006)	Concentrations and emissions of gasoline and other vapours from residential vehicle garages	Michigan, USA	Spring	15 residential garages; 36 VOCs in garage, 20 in ambient
	(Batterman, Jia, & Hatzivasilis, 2007)	Migration of VOCs from attached garages to residences: a major exposure source	Michigan, USA	Spring	15 homes; 39 VOCs indoors, 36 in garage, 20 ambient; addition to the 2006 study, however different numbers because

					additional species were included from the 2006 study
	(Jia, Batterman, & Godwin, 2008a)	VOCs in industrial, urban and suburban neighborhoods, Part 1: indoor and outdoor concentrations, variation and risk drivers	Michigan, USA	Winter; Summer removed	Consideration over both summer / winter seasons; 159 residences; 98 VOCs
Finland	(Edwards, Jurvelin, Koistinen, Saarela, & Jantunen, 2001)	VOC concentrations measured in personal samples and residential indoor, outdoor and workplace microenvironments in EXPOLIS	Helsinki, Finland	Fall/Winter	30 VOCs analyzed; personal 48h exposure

The maximum concentrations in the Health Canada led Windsor and Regina studies and the Edmonton study were consistently lower than those found in the Ottawa RAGI study. However, the RAGI median was lower in both indoor and outdoor microenvironments. Figure 4-1 and Figure 4-2 show the sum of the medians of the top ten contributing species in both of the indoor and outdoor microenvironments across the additional three Canadian studies. It should be noted that these top ten species are different for each microenvironment considered.

Figure 4-1: Median values of the sum of concentrations for the top ten constituents of indoor samples in four cities

This highlights the effect that potential outliers have on the mean, considering the RAGI maximum far outweighs those of the other studies. The median provides a more realistic understanding of the concentrations amongst study locations, showing comparable results between Ottawa, Edmonton and Regina indoor concentrations and between Ottawa, Regina and Windsor in outdoor concentrations.

Figure 4-2: Median values of the sum of concentrations for the top ten constituents of indoor samples in four cities

Figure 4-3 shows the comparison of I/O median ratios between RAGI and the other Canadian studies for the top ten contributing species. A number above the solid black line at 1 indicates that the I/O median ratio is higher for the Ottawa study. This figure indicates that approximately 70% of the top-contributing species have similar I/O ratios indicating uniformity across Canada with respect to indoor and outdoor sources.

Figure 4-3: I/O Median Ratio comparison amongst Canadian studies

The international studies tended to report results through mean concentrations with few reporting maximum and median concentrations. The RAGI study had mean and maximum indoor concentrations (of the sum of the top ten constituents) that were 2 and 12 times of the values in Batterman et al.'s 2007 study. The larger maximum concentration continues to indicate the presence of indoor outliers that should be further investigated.

The outdoor means for the studies in the United States tend to approach those of the RAGI study, differing by no more than a factor of 2.3. However, the outdoor mean and maximum for the Finland study are 7.7 and 10.9 times larger than those in the Ottawa RAGI study. Although the study in Finland revealed higher outdoor mean concentrations, the indoor was not affected nearly as much, leading to a I/O mean ratio that is 20 times as large for RAGI than Finland, indicating either fewer indoor sources or better sealed homes in Finland.

Last, the mean garage concentrations in the Dodson and Batterman studies were both approximately two times more than the mean garage concentrations in RAGI. These higher garage concentrations seem to either not have as large of an effect on the concentrations found in the home as in the Ottawa RAGI study, or the indoor sources in the Ottawa study far outweigh those in the United States.

4.6 Microenvironment Comparison

As a precursor to source apportionment modelling, comparing the microenvironments through concentration, degree of correlation and ratios is a useful practice to note similarities between the microenvironments and provide insight to how they may be related or how one influences another.

4.6.1 Concentration

The total concentration of each summation variable can be compared between microenvironments. The mean and median concentration of each summation variable in each location is shown in Table 4-9 below. Concentrations for each sample in each microenvironment are shown in Appendix F.

Table 4-9: Comparison of Mean and Median Concentrations for Summation Variables in Each Microenvironment

		MEAN ($\mu\text{g}/\text{m}^3$)	MEDIAN ($\mu\text{g}/\text{m}^3$)
SUM81	Outdoor	82.0	70.7
	Indoor	1922.4	1606.9
	Garage	2393.8	1125.9
TVOC	Outdoor	91.3	78.1
	Indoor	2025.1	1685.1
	Garage	2724.1	1288.1
BTEX	Outdoor	2.4	1.9
	Indoor	76.1	23.0
	Garage	183.2	84.2
SUM15CEPA	Outdoor	17.4	12.7
	Indoor	83.4	63.8
	Garage	60.4	42.9

It was noted that for SUM81 and TVOC, the VOC concentrations were relatively close between the garages and homes. The outdoor environment had significantly lower concentrations, as expected, due to the diluted nature of ambient air.

BTEX concentrations were highest in the garage as expected since fuel-related items are typically stored in the garage. Concentrations of BTEX were lower indoors, followed by those found outdoors.

The SUM15CEPA summation variable had highest concentrations found indoors indicating the presence of sources contributing to these higher toxicity levels inside the house. The garage microenvironment concentrations followed the indoor and as expected, the outdoor microenvironment contained the lowest concentrations of SUM15CEPA compounds.

4.6.2 Degree of Correlation

Using MiniTab17, Pearson's R correlation was calculated for the relationships between each microenvironment, for each of the summation variables. Table 4-10 summarizes the Pearson's R-values calculated using the concentrations from the 81 species suite. Results in entirety are shown in Appendix G.

In PMF bootstrapping analysis, a correlation value of 0.6 is generally accepted as a good fit for mapping the bootstrapping factor profile to the original factor profile. From this, a correlation of 0.6 can be used to confidently identify microenvironments that are correlated.

Table 4-10: Summary of correlation results for each microenvironment

TVOC		Outdoor	Garage
	Garage Indoor	0.271 0.099	0.167
SUM81		Outdoor	Garage
	Garage Indoor	0.279 0.114	0.156
BTEX		Outdoor	Garage
	Garage Indoor	0.052 0.043	0.290
SUM15CEPA		Outdoor	Garage
	Garage Indoor	0.208 -0.015	0.089

The correlation values for SUM81 and TVOC are quite low (SUM81=0.114, TVOC=0.099) for the outdoor and indoor comparison. This low correlation value indicates that there is very minimal air exchange between ambient air and the indoor environment. This is consistent with the sampling period, since samples were obtained during the winter season and windows and doors tend to remain closed.

The correlation observed between the outdoor and garage microenvironment (SUM81=0.279, TVOC=0.271) as well as indoor and garage microenvironments (SUM81=0.156, TVOC=0.167) were determined to be weakly positive. This is determined through the concept that strongly correlated data would have a correlation value that approaches 1, where a correlation value of 1 would indicate perfectly mixed data. These relationships give insight to the movement between microenvironments. The garage is typically more permeable than the home, and the outdoor and garage microenvironment have more similar sources than those observed in both home and garage. This could be why there is a higher correlation observed between outdoor and garage than indoor and garage.

Correlations for BTEX and SUM15CEPA followed similar trends. Both show little correlation between outdoor and indoor (BTEX=0.043, SUM15CEPA=-0.015). There is insignificant correlation shown between the outdoor and garage microenvironments for BTEX (BTEX=0.053) indicating independent sources contributing to each microenvironment. There is some correlation observed between the garage and indoor microenvironment for BTEX compounds (BTEX=0.290), which aligns with the lack of BTEX sources inside of the home and therefore any BTEX found within the home is most likely observed from garage sources. The remaining correlations are not significantly high, however the ratios provided in the next section provide further insight into the relationship between microenvironments.

4.6.3 Ratios

Often, ratios of concentrations between two microenvironments can be examined to point out a possible source-receptor relationship and to provide insight to the role of air exchange among the microenvironments. This can be used in a complementary way with the correlation analysis presented earlier.

Large indoor/outdoor median concentration ratios for SUM81, TVOC and BTEX summation variables (19.7, 18.3, 12.1, respectively), as shown in Table 4-11, indicate that the concentrations found within the indoor environment are largely from sources within the microenvironment itself and are of a much higher magnitude than the outdoor microenvironment median concentrations. Comparable ratios exist between the garage and outdoor environments, with the BTEX Garage/Outdoor ratio pointing to Garage levels of BTEX species that are 48 times that of the ambient concentrations. This reiterates how essential it is to manage the garage microenvironment, considering the health concerns associated with BTEX compounds.

Table 4-11: Microenvironment Ratios for Summation Variables

Variable	Mean	Median	Minimum	Maximum
I/O - SUM81	27.8	19.7	3.0	107.8
I/O - TVOC	26.2	18.3	2.6	112.3
I/O - BTEX	34.8	12.1	1.8	697.5
I/O - SUM15CEPA	6.3	4.8	0.5	21.6
G/O - SUM81	27.9	14.8	2.4	300.0
G/O - TVOC	29.3	16.0	2.3	307.7
G/O - BTEX	92.9	48.0	1.5	477.6
G/O - SUM15CEPA	5.0	3.1	0.4	38.7
G/I - SUM81	1.4	0.8	0.1	8.3
G/I - TVOC	1.5	0.9	0.1	8.6
G/I - BTEX	5.4	4.1	0.2	26.3
G/I - SUM15CEPA	1.0	0.6	0.1	9.8

The garage/indoor BTEX ratio (Median 4.1, Mean 5.4) points to the potential of strong contributions from the garage to indoor concentrations when there is infiltration from the garage to the indoor environment. The ratios closer to one for SUM81 and TVOC indicate similar concentration levels between the two microenvironments but still point to the possibility of exchange between the garage and indoors

Bari et al. report a high indoor/outdoor (I/O) ratio as well in both seasons of their Edmonton study. I/O ratios close to 1.0 were noted for individual species such as Freon compounds, bromomethane, chloromethane and carbon tetrachloride, indicative of contributions from outdoor sources. They also report an I/O between 2 and 9 for BTEX species, which was influenced by product use and building materials as well as attached garage influences (Bari et al., 2015). This I/O ratio is inline with the I/O of 12.1 noted for BTEX in this Ottawa study.

In the study conducted by Jia et al., I/O ratios were observed to be in between 1 and 10 in most cases. It was noted that for cases near unity, compounds were determined to appear from outdoor sources. They found this was the case in chlorinated compounds as mentioned in Bari et al. as well as benzene—but not other aromatics. Those species with ratios above 1.5 but below 10 were noted to indicate both indoor and outdoor sources. This was the case for aromatic compounds and light n-alkanes as well as TVOC. Last, it was noted that ratios above 10 indicated indoor sources were the primary source for the compound. This included terpenes, heavy n-alkanes, styrene and cymene. It was also noted that the I/O ratios for BTEX, trimethylbenzene isomers, ethyl toluene and chlorinated compounds decreased in the winter season due to the higher outdoors concentrations (Jia et al., 2008a)

Batterman calculated G/I ratios in their Michigan study. Ratios for benzene (16.6) and their garage tracer (22.6) were expected to be equal. They believed that the lower G/I ratio for benzene was indicative of the influence of outdoor concentrations and once the ratio was adjusted for the outdoor benzene influence, identical G/I ratios were observed in homes without smokers. It should be noted that prior to results from this adjustment indicating otherwise, this lower benzene ratio could be interpreted as the presence of indoor benzene sources. VOCs said to be from garage sources, including trimethylbenzene, xylene, ethyl toluene, cyclohexane, isopropyltoluene and benzene were reported to have high G/I ratios, over 10 (Batterman et al., 2007). The ratios for these individual species are much higher than those found for the median ratio in the RAGI study, however some of the alkanes and terpenes had more sources in the home and therefore more ratios approaching those calculated for RAGI. This discrepancy could also indicate higher indoor concentrations in Ottawa homes. The authors also note that the houses appeared to be “tighter” than those in literature values based on their air exchange rates (Batterman et al., 2007).

4.6.4 Outlier Analysis

An outlier analysis makes it possible to identify species and samples that are outliers from regular sample data and consider those for down-weighting or elimination from the source apportionment analysis. Two approaches were used in combination to identify outliers: viewing time series data, and box-whisker plots summarizing the distribution of the data.

4.6.4.1 Time Series

Time series analysis is normally undertaken on data that has been collected with the same sampling and analysis protocol for a source, the only variable between data points being the time of the sample and any factors that are directly related. The current data set involves differences in time as well as the source (home) that was sampled at a given time, with the difference in source potentially the more important factor. Thus the analysis presented below is not truly a “time series” analysis. However, a series plot of the summation variables measured over time and over the 36 houses in each microenvironment still allows the identification of some potentially problematic samples. Of greatest magnitude are some of the samples for the garage microenvironment as shown in the TVOC line plot in Figure 4-4.

Figure 4-4: Line plot of TVOC across microenvironments

Figure 4-5 and Figure 4-6 show the same time series plot for BTEX and SUM15CEPA.

Figure 4-5 shows what appears to be a home with three consecutive days of indoor samples that are outliers. These samples were all from the same home (19-1, 19-2 and 19-3). Analysis of the home 19 questionnaire indicates that the residents had recently completed extensive renovations to the living area and front hall area including painting with low VOC paint, working with expanding foam grout and construction adhesives. These products likely contributed to the outliers observed in Figure 4-5 and therefore these samples were excluded during analysis since these were uncharacteristic events confined to the one home. The samples for the garage series are better distributed and there are no clear outliers for the BTEX species.

Figure 4-5: Line Plot of BTEX species across microenvironments

Figure 4-6: Line plot of SUM15CEPA concentrations across microenvironments

The line plot for SUM15CEPA, as shown in Figure 4-6 shows two outliers above 500 $\mu\text{g}/\text{m}^3$ for garage and indoor sampling that should be further investigated. Furthermore, there is a sample for the outdoor SUM15CEPA concentrations that warrants further investigation considering the relatively very low concentrations that the outdoor microenvironment typically exhibits.

The samples identified as outliers through the time series were noted and considered for exclusion in combination with the box plots (next section) as well as during the PMF analysis to ensure that samples that are not representative of typical circumstances are excluded from analysis.

4.6.4.2 Box Plots

Box plots can be used to identify outliers and the distribution of data graphically based on summary statistics. Figure 4-7 (MiniTab Inc, 2015) shows a typical box plot with whiskers identifying the upper and lower quartiles, the box representing the middle 50% of the distribution and the asterisk (*) representing outliers which are more or less than 1.5 times the value of the interquartile range.

Figure 4-7: Example of a typical box plot showing interquartile range, whiskers and outliers

In this example, “A” is pointing to the outlier, which is considered an extreme value that is larger than 1.5 times the interquartile range, identified by “C”. The highest and lowest 25% of data points that do not fall outside $1.5 \times \text{IQR}$ are represented within the whiskers identified as “B” and “D” in Figure 4-7.

From Figure 4-8 to Figure 4-10, it was noted that 22 samples amongst the ~300 samples across all microenvironments should be considered further as potential outliers. These outliers make up approximately 7.3% of the sample size, therefore should they be excluded this would be a reasonable percentage to exclude without skewing the sample size.

Figure 4-8: Boxplot of TVOC across homes in the Outdoor Microenvironment (The outlier samples are identified by home ID - sampling day)

Figure 4-9: Boxplot of TVOC across homes in the Indoor Microenvironment (The outlier samples are identified by home ID - sampling day)

Figure 4-10: Boxplot of TVOC across homes in the Garage Microenvironment (The outlier samples are identified by home ID - sampling day)

Similar boxplots were created for the SUM81 species suite as well, identifying the same outliers. These outliers are summarized in Table 4-12 below.

Table 4-12: Summary of Outlier Samples for each Microenvironment (The outlier samples are identified by home ID - sampling day)

Location	Sample
Outdoor	27-2
	28-3
Indoor	17-3
	19-1
Garage	14-3
	27-2
	27-3
	28-3
	30-1
	36-1
	36-2
	38-1
	38-1
	38-3

The same practice was applied to each of the top ten contributing species in each microenvironment to further examine the samples and scrutinize the smaller subset of species that have the greatest effect on the overall concentration. This resulted in several outliers for some of the species; however, some of these outlying samples were those obtained on consecutive days within the same home. This is shown in the labelled outliers (H141, H142, H143) in Figure 4-11, where the letter and first two digits represent the house code and the last digit shows the day of sampling—1st, 2nd or 3rd day.

Figure 4-11: Boxplot for Ethanol (S011) showing species outliers in the Indoor Microenvironment

An outlying home or sample location could indicate a source unique to the home or a microenvironment with poor ventilation. These outlying circumstances can interfere with the model algorithm, which is seeking to capture trends and should be considered for exclusion during analysis. By repeating this procedure for the top ten contributing species in each microenvironment, common outlying samples can be identified and considered for exemption.

5 PMF Modelling Results

Best practice guidelines, the US EPA PMF user guide, and other peer-reviewed literature were consulted throughout the modelling in order to reach a well-supported analysis (Norris et al., 2014) (Norris et al., 2008) (Reff et al., 2007).

As discussed in Section 4.3, if a species was identified as a marker species - regardless of the number of samples that are below detection limit - the species was retained for analysis. However, retaining species with a large number of samples below detection limit reduced the variability between samples and therefore reduced the effectiveness during analysis. To minimize this effect, the input files for each microenvironment were scrutinized for the number of samples below detection limit and the experimental uncertainty of 10% used for all species were increased in proportion to the fraction of data points below detection limits. Species with a %BDL between 10% and 25% were set at an uncertainty of 20% and anything above 25% BDL was set to have an uncertainty of 30%.

After the input concentration and uncertainty files were loaded into PMF3 and the S/N ratios were determined, species with a S/N below 0.2 were categorized as “bad” and species with S/N between 0.2 and 2 categorized as “weak” for the outdoor microenvironment. Species in the garage and indoor microenvironments were categorized as “bad” for S/N below 1 and “weak” for S/N between 1 and 2.

5.1 Outdoor Microenvironment

Analysis started with the outdoor microenvironment data, as the sources in ambient air were expected to be less variable than those in different homes and garages, and therefore

easier to model. To begin, species were categorized based on their S/N ratios as described in Section 3.7.2 and 5. Once the model was run, those species with many samples with high residuals and those with a high sum of squared residual value were set to weak if already categorized as strong, or set to bad if already set as weak and was not considered a valuable marker species. Supported by Huang et al. (1999) and Ito et al. (2004), species with “analytical difficulties or anomalous values” were excluded if they were not useful tracers resulting in an improved analysis (Huang et al., 1999). This process was repeated until a satisfactory Q/Q_{exp} and range of $Q(robust)$ was reached, as suggested in Kim et al.’s work (Kim et al., 2003) (Kim et al., 2003). Once a solution was found for 3 factors the process was repeated to find the best-fit solution for an increasing number of factors. Figure 5-1 shows the comparison of model runs for solutions with 3- to 8-factors for the same input files (i.e. those categorized only by the S/N ratio rules stated in Section 3.7.2) changing only the p-value across runs

Figure 5-1: Effect of changing the number of factors on Q -value in the Outdoor microenvironment

The figure shows the Q-value on the primary axis and the maximum sum of squared residual on the secondary axis. The rule discussed in Section 3.7.2 was used to identify the ideal number of factors to use in analysis.

From Figure 5-1 it is difficult to visually determine where a definite steep slope changes to a shallower slope. However, from the calculated slopes and differences between the slopes in Table 5-1, it is observable that the slope has changed to a shallow slope as described in Zhao et al. (2004) for a 6-factor solution.

Table 5-1: Summary of Differences between Slopes for the Outdoor Microenvironment

Number of Factors	Q(Robust)	Slope(robust)	Difference
3 Factors	18675		
		2989	
4 Factors	15686		849
		2140	
5 Factors	13546		471
		1669	
6 Factors	11877		485
		1184	
7 Factors	10693		-8
		1191	
8 Factors	9502		

Table 5-2 summarizes the performance of the resolved 6-factor solution. This table summarizes the input parameters to achieve this stable solution as well as the indicators that signify stability. This run used the outdoor input file and shows that C3 was set to 0 where C3 is the parameter that increases uncertainty by a percentage. Number of factors (p) is set to 6 and the species categorized as weak or bad are listed based on the S/N ratio range shown in the table. Additionally, if species that were originally categorized as weak were found to fit poorly following the initial run and did not add value to interpretation, they were then categorized as bad in following runs.

The Qrobust and Qtrue ranges are below 1.0 indicative of stability and the Q for the model is within 34% of the expected Q. There were 26 instances where species in samples had a residual greater than 3 or less than -3 however, these were due to only a few samples per species, rather than by one or two problematic species across many samples. Bootstrapping was applied using a correlation r-value of 0.6 over 100 bootstrap runs. With the exception of Factor 4, 100% of the runs were mapped to the resolved base factors. Factor 4 had 98 bootstrap factors mapped to base factors, which are still a fair number mapped, indicative of a robust solution. Table 5-3 shows a summary of the contributing marker species for each factor and the sources that the species may represent. All of the species that are shown to contribute large percentages of their concentration to the factor are listed, however only those with a “Y” in the outdoor location column are typically found in the microenvironment. These marker species are essential for interpretation of the factors in the following sections.

Table 5-2: Performance Summary for the Outdoor Microenvironment

Input and Configuration	
Input Filename	RAGI_outdoor_PMFinpud_Sep9_BIN.xlsx
C3	0
Factors (<i>p</i>)	6
Total Species	81
Species – Weak $0.2 < S/N < 2$	37 – Acetylene, Ethane, Acetonitrile, Acetaldehyde, Octane, Acetone, Isopropyl Alcohol, Isoprene, 1-Pentene, MEK (2-Butanone), 2-Methylbutane, Methyl Acetate, Carbon Disulfide, Cyclohexane, Dichloromethane, 2, 2-Dimethylbutane, Ethylacetate, MIBK, Methanol, Freon 134A, Styrene, Benzaldehyde, 1-Octene, Butylacetate, 1, 2, 3-Trimethylbenzene, 1, 3, 5-Trimethylbenzene, Naphthalene, Trichloroethene, 1, 1, 1-Trichloroethane, a-Pinene, Limonene, Camphene, 1, 4-Dichlorobenzene, Carbon tetrachloride, Undecane, Tetrachloroethene, Dodecane
Species – Bad $S/N < 0.2$ Excluded from analysis	9 – Ethylene, Ethanol, 2-Methylpentane, Methyl-t-Butyl Ether (MTBE), p-Cymene, b-Pinene, 1, 2-Dichlorobenzene, 1, 3-Dichlorobenzene, Dibromochloromethane
Excluded Samples	RAGI-28-1 RAGI-32-3 RAGI-33-3
Stability	
Q_robust (range)	3434 (0.05)
Q_true (range)	3469 (0.05)
Q/Qexp	1.34
Σd^2	<0.06
Fit	
R^2	$23 < R^2=0.50$; $24 > R^2=0.90$; median $R^2 = 0.76$
# residuals > 3	26 > 3
High residuals (#, R^2)	Propane (3, 0.87)
Robustness	
Bootstrapping R	0.6
Number of runs	100
Bootstrapping factors mapping	Factor 1 = 100 / 0 / 0 / 0 / 0 / 0; 0 unmapped Factor 2 = 0 / 100 / 0 / 0 / 0 / 0; 0 unmapped Factor 3 = 0 / 0 / 100 / 0 / 0 / 0; 0 unmapped Factor 4 = 0 / 0 / 0 / 100 / 0 / 0; 0 unmapped Factor 5 = 0 / 0 / 0 / 0 / 98 / 0; 2 unmapped Factor 5 = 0 / 0 / 0 / 0 / 0 / 100; 0 unmapped

Table 5-3: Summary of Marker Species for Each of the Evaluated Factors in the Outdoor microenvironment

Factor	Species ID	Species Name	Marker?	Contribution	Found Outdoors?	Type of Source												
						Exhaust		Volat.		Paints	Cleaners	Solvents	Degreasers/ Lubricants	Furniture/ Wood	Personal Care	Biogenic	Industry	Other
						Gas	Diesel	Gas	Diesel									
1	S008	Acetaldehyde	Y	53%	Y									X				wild fires
	S016	Acrolein (2-Propenal)	Y	72%	Y													gas stove, wild fires
2	S012	Chloromethane	N	53%														
	S025	Isopropyl Alcohol	Y	57%	Y										X			
	S044	2-Methylbutane	Y	60%	Y	X												
	S097	1,2-Dichloroethane	Y	52%	Y					X	X	X					vinyl chloride	paint removal
	S111	Benzaldehyde	Y	51%	Y											X		toluene oxidization
	S149	Freon 12	Y	53%	Y							X						refrigerant
	S157	1,1,1-Trichloroethane	Y	50%						X	X	X	X					
	S172	Freon 11	Y	53%	Y							X						refrigerant
	S180	Carbon tetrachloride	Y	55%	Y							X						propellant, global background
	S189	Freon 114	Y	54%	Y							X						refrigerant
	S193	Freon 113	Y	53%	Y							X						refrigerant
3	S141	1,2,3-Trimethylbenzene	Y	68%	Y	X	X											
	S142	1,2,4-Trimethylbenzene	Y	73%	Y	X	X	X	X			X						
	S143	1,3,5-Trimethylbenzene	Y	66%	Y	X	X											

	S145	3-Ethyltoluene	Y	58%	Y	X	X										
	S146	4-Ethyltoluene	Y	60%	Y	X											
	S154	Naphthalene	Y	69%	Y	X											general combustion, mothballs
	S183	Undecane	Y	50%	Y		X	X	X	X	X	X					
4	S019	t-2-Butene	Y	63%	Y			X									
	S023	Butane	Y	42%	Y					X	X	X					
	S024	Isobutane	Y	45%	Y	X	X	X									
	S035	t-2-Pentene	Y	51%	Y			X									
5	S001	Acetylene	Y	48%	Y										X		
	S007	Propene	Y	49%	Y	X										petro-chem refining	
	S015	1,3-Butadiene	Y	62%	Y	X	X										
	S030	Isoprene	Y	53%	Y	X	X			X	X	X			X		
	S083	Toluene	Y	43%	Y	X	X	X	X				X				BTEX
	S093	Methylcyclohexane	N	41%													Hexane derivative
	S105	3-Methylhexane	N	64%													Hexane derivative
	S106	Heptane	Y	48%	Y	X		X									Evap > volatilization
	S133	2-Methylheptane	N	50%													
	S136	Octane	Y	41%	Y	X		X									Evap > volatilization
	S155	Nonane	Y	42%	Y			X									
	S186	Tetrachloroethene	Y	41%								X					
6	S004	Methanol	N	66%													
	S046	Methyl Acetate	N	35%													
	S079	Ethylacetate	Y	39%										X			
	S137	Butylacetate	N	42%													

5.1.1 Factor 1 – Wood/Charcoal Combustion Processes

Figure 5-2 shows the factor profile and concentrations outputs from PMF for factor 1 as in the example presented earlier in Section 3.7.3.

The factor was found to account for 53% of the measured acetaldehyde and 72% of the measured acrolein which are compounds that are representative of combustion processes such as heated cooking oil, barbeques or wood-burning fireplaces as well as biomass smoke from forest fires (Seaman et al., 2009). The factor has noticeably higher concentrations to the total mass measured at 4 of the samples. This could be due to homes owning wood burning fireplaces that may exhaust to the outdoors, near the sampling equipment. The participants at house 27 (27-2) and house 48 (48-1) indicated in the baseline questionnaire that the home had a wood-burning stove that they typically used during the winter, however none of the four high concentration samples had any daily diaries that indicated they were burning any wood. Although all homes may not have wood burning fireplaces, they may display contributions to this factor through the influence of neighbouring homes, considering that this factor is resolved to the outdoor microenvironment.

Acrolein and acetaldehyde were selected for highlighting because they contribute more than 40% of each species' total mass to Factor 1. Factor contribution pie charts for each species as shown in Figure 5-3 present another way of looking at the overall results.

Figure 5-2: Factor 1 outdoor microenvironment profile and corresponding concentrations

Figure 5-3: Factor Contribution Pie Chart for Acrolein (S016)

This figure demonstrates the 72% contribution previously observed.

5.1.2 Factor 2 – Global Background

The plots generated for Factor 2 are shown in Figure 5-4. Species that contributed more than 50% of their total mass to the factor were considered to be marker species. This was a higher than normal threshold due to the large number of species that contributed between 20% and 30% of their total concentration to the factor.

The marker species in Table 5-3 indicate that this factor was resolved to represent global background, persistent species. This global background factor was also observed in both factor contributes fairly uniformly across all samples.

Figure 5-4: Factor 2 outdoor microenvironment profile and corresponding concentrations

Bari et al.'s and McCarthy et al.'s studies found factors resolved to a Global Background source, which were also characterized by the presence of halogenated VOCs like 1,2-dichloroethane, chloromethane, 1,1,1-trichloroethane, carbon tetrachloride and Freon 11, 12, 113 and 114 (Bari et al., 2015) (McCarthy et al., 2013). The lower part of Figure 5-4 shows that the distribution of factor concentrations is quite reasonable, with no extreme outliers. The oddity in this data was the sample points that reached zero. There was unfortunately no explanation found in the diaries for these samples that met a zero contribution.

5.1.3 Factor 3 – Traffic Exhaust Emissions

Similar to the methodology applied in Factor 2, only species for which the factor accounted for over 50% of the measured total mass were considered as markers for the third factor. Top species identified in this way include 1,2,3-trimethylbenzene (68%), 1,2,4-trimethylbenzene (73%), 1,2,5-trimethylbenzene (66%), 3- and 4-ethyltoluene (58%, 60%), naphthalene (69%) and undecane (50%). Factor 3 was interpreted to represent traffic exhaust emissions, similar to studies conducted by Bari et al. (2015) and Edwards et al. (2001). These species are shown in Figure 5-5 below, represented by the red dots on the secondary % of species axis. The factor has lower and somewhat more variable concentrations across the samples than Factor 2, as shown in the bottom part of Figure 5-5. The variability of these factor concentrations indicate that this is a commonly observed factor amongst most homes with some homes showing higher concentrations, most likely representative of a home in a more urban area or a home that is located close to a larger roadway.

Figure 5-5: Factor 3 outdoor microenvironment profile and corresponding concentrations

5.1.3.1 BTEX Ratios as indicators of vehicle traffic emissions

Yurdakul et al. (2013) used toluene-to-benzene ratios (T/B) to provide insight to the relative abundances of traffic and non-traffic sources, where a ratio lower than 2 is indicative of a strong influence of motor vehicle emissions, rather than non-traffic sources (i.e. solvent evaporation). Additionally, an m-, p-xylene to ethylbenzene (X/E) ratio was used to indicate the “age” of the VOCs where a smaller ratio is indicative of older VOCs and therefore can be designated to either a long- or short-range emission classification (Yurdakul et al., 2013). By applying these ratios in source apportionment, it is possible to increase confidence in the interpretation of resolved factors. For the outdoor microenvironment, it was determined that both the mean and median T/B ratio was 1.4 and the mean and median X/E ratio was 2.6 for each. These relatively low values indicate the strong influence of traffic emissions that are relatively old. This is consistent with the interpretation of Factor 4 since the homes chosen for the study were mostly not immediately close to a major highway or arterial road and traffic sources in ambient air would have migrated from major traffic routes to suburban homes, thereby classifying the traffic exhaust as a long-range emission source.

5.1.4 Factor 4 – Industrial and Mobile Evaporative Emissions

Factor 4 accounted for significant percentages of the total mass measured for 4 species: trans-2-butene and trans-2-pentene at 63% and 51% followed by butane and isobutene at 42% and 45% of their total mass. A less restrictive species total mass above 40% was considered for this factor since upon observation of the factor profile, there are very few species that have high concentrations. The presence of these alkene species may be

indicative of industrial and vehicular evaporative emissions (Bari et al., 2015) (Jorquera & Rappengluck, 2004).

Figure 5-6 shows the factor profile PMF output mentioned. Concentrations of the factor to measured total mass are at relatively low levels but show distinctly higher concentrations at a few samples. This could be indicative of homes that were located closer to sources that would emit evaporative emissions, perhaps a home close to an automotive shop or a parking garage. The baseline questionnaire indicated that house 30, day 1 (30-1) was located near a gas pipeline, which could be reasoning for the higher concentration in Figure 5-6.

5.1.5 Factor 5 – Petrochemical and Other Industrial Sources

Factor 5 accounts for some species that were indicative of petrochemical and other industrial sources. Figure 5-7 shows the factor contribution profile and concentrations output from PMF. The highest attribution was for 3-methylhexane, which is not a typical species marker, but is noted in Civan, Kuntasal and Tuncel's 2011 study as a hexane derivative and is classified as representative of industrial emissions (Civan et al., 2011). Furthermore, 62% of 1,3-butadiene was attributed to this factor where 1,3-butadiene is released into the atmosphere during combustion of organic matter. This can include natural sources such as forest fires and anthropogenic activities like prescribed burning, residential/commercial space heating, petrochemical plants, refineries and emissions from other industries (Curren et al., 2006).

Figure 5-6: Factor 4 outdoor microenvironment profile and corresponding concentrations

Figure 5-7: Factor 5 outdoor microenvironment profile and corresponding concentrations

Additional species including acetylene, propene, isoprene, toluene, methylcyclohexane, heptane, 2-methylheptane, octane, nonane and tetrachloroethene are all associated with industrial uses such as petrochemical refining (Bari et al., 2015) (Civan et al., 2011) (Dumanoglu et al., 2014).

The variability of the concentrations in the Factor Concentrations graph with no extreme outliers indicates that this factor is consistent amongst most samples and likely varies based on the proximity to these resolved sources.

5.1.6 Factor 6 – Cleaners / Solvents

Factor 6 accounted for 66% of the measured methanol, but methanol is not considered a marker species in any of the literature sources. Because of this, methanol was disregarded and species with more than 30% of their total mass explained by this factor were considered for marker analysis. These included methyl acetate (35%), ethyl acetate (39%) and butyl acetate (42%), which are all ketones that are common in solvent use in industrial processes (Cai et al., 2010) (Dumanoglu et al., 2014).

Figure 5-8 shows the factor profile and concentrations for the sixth factor. There is much variability in the factor concentration graph, demonstrative of samples that may have more exposure to solvents. There are no homes with extremely high concentrations, which, when considering this factor resolution makes sense as concentrations would likely be diluted and somewhat consistent across sample locations depending on the location of nearby sources.

Figure 5-8: Factor 6 outdoor microenvironment profile and corresponding concentrations

5.2 Indoor Microenvironment

The indoor microenvironment posed more of a challenge due to the variability of the sources between homes. Depending on things like what homeowners store in the home, what they use for cleaning or what equipment they use for cooking, variable amounts and types of VOCs will be emitted. This variability makes it more difficult to assign a universal factor or source amongst homes. The same procedure presented in Section 5.1 for the outdoor microenvironment was applied for determining the ideal number of factors and results are shown in Figure 5-9.

Figure 5-9: Effect of changing the number of factors on Q -value in the Outdoor microenvironment

The slope was calculated between factors and summarized in Table 5-4 to determine at which point the slope stops changing from rapid to slow. Due to the large drop in slope

from 5 to 6 factors and the levelling of slope from 6 to 7 factors, the ideal solution will be a 6- or 7-factor solution.

Table 5-4: Summary of Differences between Slopes for the Indoor Microenvironment

Number of Factors	Q(Robust)	Slope(robust)	Difference
4 Factors	74904		
		6363	
5 Factors	68541		1297
		5066	
6 Factors	63475		644
		4423	
7 Factors	59052		556
		3867	
8 Factors	55186		52
		3815	
9 Factors	51371		

From this analysis, it was easier to run the model focusing on a 6- or 7-factor solution rather than the anticipated range from 4- to 9-factor solutions. Using a similar method to that which was employed for the outdoor analysis, Q/Qexp, residuals and sum of squared residuals were analyzed for each species in both factor solutions to determine the goodness of fit and whether that species should be excluded from analysis. From this, a 6-factor solution was determined to be the best fit. Table 5-5 summarizes the performance of the indoor model solution.

Table 5-5 summarizes the performance of the resolved 6-factor solution. Similar to the process for the outdoor microenvironment analysis, this table summarizes the input parameters to achieve this stable solution as well as the indicators that signify stability. Because of the extra variability in the indoor analysis, values between 5 and 15 were considered for extra modelling uncertainty (C3). Without the extra modelling uncertainty, Q-values were as much as 17 times that of the expected Q-value—even with higher factor solutions considered. The combination of a 6-factor solution and a C3 value of 15% resulted in a more reasonable Q-value that is 1.74 times that of Q_{expected} . Furthermore, species with an S/N below 1 were excluded from analysis and species with S/N ratios between 1 and 2 were classified as weak for this microenvironment. As previously mentioned, this practice is well within literature values and was necessary to obtain a reasonably stable result. Proceeding with analysis, those species largely contributing to a high Q/Q_{expected} or those with many residuals above 3 were weakened or excluded from analysis, following consultation of the marker species to ensure that there were no issues with exclusion of a species. The Q_{robust} and Q_{true} ranges are below 1, indicative of stability between runs and the Q for the model is within 74% of the expected Q, which is still a reasonable result. There was only 1 sample where the species had a residual greater than 3. Bootstrapping was applied using a correlation r-value of 0.6 over 100 bootstrap runs. Of all the solutions, this 6-factor solution was the most robust solution. The smallest fraction of correctly mapped factors was 88% (for Factor 1) and 3% remained unmapped. Although this may not be as robust as the outdoor microenvironment solution, the minimal number of unmapped factors and the remaining factors mapped correctly over 90% of the time indicates that this is a reasonably robust solution. Table 5-6 shows a summary of those

species that contribute a higher percentage of their total mass to each factor and the sources that they may represent. The table lists the location that the marker species may commonly originate from allowing for consideration of other sources should the marker species typically originate from another source or microenvironment. These marker species are essential for interpretation of the factors in the following sections.

Table 5-6: Summary of Marker Species for each of the Evaluated Factors in the Indoor Microenvironment

Factor	Species ID	Species Name	Marker?	Contribution	Found Indoors? (Y/N)	Type of Marker									Other
						Gas Exhaust	Diesel Exhaust	Gasoline Volatilization	Diesel Volatilization	Paints/ Cleaners/ Solvents	Degreasers/ Lubricants	Furniture/ Wood	Personal Care	Biogenic	
1	S025	Isopropyl Alcohol	Y	20%									X		chem/pharm.
	S051	Benzene	Y	27%		X	X	X	X						BTEX; oil/gas
	S063	Cyclohexane	Y	20%				X	X						oil/gas industry
	S077	Hexane	Y	24%	Y	X	X	X	X			X			
	S093	Methylcyclohexane	N	23%	Y			X		X					Hexane derivative
	S104	2-Methylhexane	Y	20%		X									oil/gas industry
	S136	Octane	Y	31%		X		X							evap > volatilization
	S142	1,2,4-Trimethylbenzene	Y	21%	Y	X	X	X	X	X					
	S143	1,3,5-Trimethylbenzene	Y	21%		X	X								
	S145	3-Ethyltoluene	Y	25%		X	X								
	S146	4-Ethyltoluene	Y	27%		X									
2	S172	Freon 11	Y	23%						X					refrigerant
	S019	t-2-Butene	Y	60%				X							
	S023	Butane	Y	50%	Y					X					
	S033	1-Pentene	Y	49%		X									
	S035	t-2-Pentene	Y	55%				X							
3	S046	Methyl Acetate	N	50%											
	S136	Octane	Y	32%		X		X							Evap > volatilization
	S141	1,2,3-Trimethylbenzene	Y	53%		X	X								
	S142	1,2,4-Trimethylbenzene	Y	38%	Y	X	X	X	X	X					

	S143	1,3,5-Trimethylbenzene	Y	40%		X	X							
	S145	3-Ethyltoluene	Y	33%		X	X							
	S146	4-Ethyltoluene	Y	34%		X								
	S155	Nonane	Y	78%				X						
	S176	Decane	Y	91%	Y		X	X	X	X				
	S183	Undecane	Y	88%	Y		X	X	X	X				
	S188	Dodecane	Y	50%			X	X	X	X	X			
4	S083	Toluene	Y	45%		X	X	X	X		X			BTEX
	S112	Ethylbenzene	Y	74%		X	X	X	X					BTEX
	S113	m-, p-Xylene	Y	75%	Y	X	X	X	X		X			BTEX
	S114	o-Xylene	Y	75%	Y	X	X	X	X		X			BTEX
	S156	Trichloroethene	Y	47%	Y					X	X	X		
5	S012	Chloromethane	N	52%										
	S020	Acetone	Y	53%	Y					X			X	
	S025	Isopropyl Alcohol	Y	58%									X	
	S030	Isoprene	Y	51%	Y	X	X			X				X
	S050	Carbon Disulfide	N	65%										
	S099	MIBK	Y	41%						X				
	S110	Styrene	Y	65%	Y					X		X		printer ink
	S111	Benzaldehyde	Y	84%										X toluene oxidization
	S156	Trichloroethene	Y	38%	Y					X	X	X		
	S169	b-Pinene	Y	60%	Y					X				cleaner - pine smell
	S172	Freon 11	Y	41%						X				refrigerant
	S180	Carbon tetrachloride	Y	53%						X				global background
6	S188	Dodecane	Y	41%			X	X	X	X	X			
	S002	Ethylene	Y	66%		X	X	X						
	S007	Propene	Y	67%		X								petro-chem. refining
	S015	1,3-Butadiene	Y	66%		X	X							
	S172	Freon 11	Y	31%						X				refrigerant

5.2.1 Factor 1 – Environmental Tobacco Smoke

The factor profiles and contribution graph is shown in Figure 5-10. This figure demonstrates the absence of notable species that contribute large percentages of the total mass to the factor. It is for this reason that species above a 20% contribution were considered as marker species for factor analysis. Comparing the most notable species, octane (31%), benzene (27%), 3-, 4-ethyltoluene (25% and 27%, respectively) and hexane (24%) to recent literature source apportionment work resulted in resolving this factor to environmental tobacco smoke and other combustion sources. Although many of the species identified could be related to fuel sources, it was determined that the following factors will better exemplify these sources. These top contributors have been directly associated with tobacco smoke decay (Xie et al., 2003). Having personally conducted the field sampling, it was noted that some of the participants were smokers and would simply smoke outside, even though the homes recruited were initially screened for non-smokers. This, as well as visitors who bring in the compounds associated with tobacco smoke could be contributing to this factor. The factor concentrations (lower part, Figure 22) show about a dozen samples over 6 homes with notably higher concentrations. Samples 41-1, 41-2 and 41-3 had the highest contributions however the daily diary for this home unfortunately revealed no reasoning for these high concentrations. It should be noted that there were no species that contributed high percentages of their total mass to this factor. This made it difficult to assign a source to this factor resulting in some uncertainty in assigning the tobacco smoke source to this profile.

Figure 5-10: Factor 1 indoor microenvironment profile and corresponding concentrations

5.2.2 Factor 2 – Gasoline Evaporation

For analysis of the second factor, species with more than 50% of their measured mass accounted by this factor were considered as source markers as per the factor profile and species concentration graphs in Figure 5-11 below. These included trans-2-butene (60%), trans-2-pentene (55%), butane (50%), methyl acetate (50%) and 1-pentene (49%). Analysis from Bari et al. (2015) determined that the dominant alkene species such as trans-2-pentene, cis-2-butene, trans-2-butene, 1-pentene, 2-methyl-2-butene and 3-methyl-1-butene, could be due to the presence of attached garages and therefore it was interpreted as fuel evaporation (Bari et al., 2015).

Na et al. (2004) also determined that concentrations from i-pentane, n-butane, n-pentane, i-butane, trans- and cis-2-butene were representative of gasoline vapour as well (Na et al., 2004). It was thereby determined that this factor is representative of fuel evaporation infiltrated from the attached garage. This factor emerges with noticeably higher concentrations in approximately 12 samples from three homes (lower part, Figure 5-11). Daily diaries for samples 19-1, -2 and -3 were consulted and it was determined that the owner of this home conducted repairs on his three motorcycles in the garage over the winter which would contribute to the gasoline evaporation factor. Secondly, samples 37-1 and 37-2 were consulted for any irregularities. The diary indicated that there were two cars parked in the garage at this home rather than the average one car and that there was no sample for the third day. This could explain the high evaporative emissions noted as well in the figure.

Figure 5-11: Factor 2 indoor microenvironment profile and corresponding concentrations

5.2.2.1 *BTEX Ratios*

As in the outdoor microenvironment, the T/B and X/E mean and median ratios were calculated for the indoor microenvironment. The mean and median for T/B was calculated to be 7.0 and 6.4 whereas the X/E ratio was 3.3 and 3.2. This indicates that perhaps the source of these species is from non-exhaust emissions, perhaps solvent evaporation or fuel evaporation. This is corroborated with the winter sampling period, since windows and doors tend to remain closed during the winter season, preventing most ambient traffic exhaust infiltration. The X/E ratio indicates that the vaporization has aged, but not to the extent that the outdoor microenvironment has which leads to the interpretation that BTEX ratios could be from the gasoline evaporation observed in the garage as well, documented in Section 5.3.1.

5.2.3 Factor 3 – Floor and Wall Coverings

Bari et al. (2015) associated one of their indoor factors with floor and wall coverings such as carpet, wallpaper, tiles, foam, due to the large mass fractions of C9- to C12-alkanes, trimethylbenzene isomers, n-butylbenzene, n-propylbenzene, ethyltoluene isomers and octane. Guo also conducted a source apportionment study in homes and determined that factors with large loadings of decane, nonane, 1,2,4-trimethylbenzene amongst other species were indicative of room freshener products (Guo, 2011), however this seems unlikely due to the absence of scent markers such as pinene or limonene. The study conducted in 2002 by Anderson et al. revealed one of the most significant sources to be building materials and carpeting attributed to the factor with higher alkanes (Anderson et al., 2002). Furthermore, Pekey et al. labelled a factor with considerable contributions for

decane, 1,2,3-, 1,2,4- and 1,3,5-trimethylbenzene, undecane and octane, amongst other species, as “indoor sources” in their 2013 study (Pekey et al., 2013).

Other studies that limited analysis to ambient VOC concentrations determined that factors with similar species profiles were indicative of diesel (McCarthy et al., 2013) (Civan et al., 2011). 91% of total mass for decane was contributed to this factor, as well as large contributions for undecane (88%), nonane (78%), 1,2,3-, 1,2,4- and 1,3,5-trimethylbenzene (53%, 38% and 40%), dodecane (50%), 3- and 4-ethyltoluene (33% and 34%) and octane (32%). Considering previous studies and the indoor nature of the sample location, this factor was determined to represent floor and wall coverings rather than a diesel related source.

The factor seemed to average relatively normal concentrations in the Factor Concentrations graph for most of the samples, however the clear outlier would be the samples from house 19 over the three days considered. Upon consultation of the daily diary, it was discovered that the home had recently finished extensive renovations throughout the home, which is likely the reason for the high concentration observed.

Figure 5-12: Factor 3 indoor microenvironment profile and corresponding concentrations

5.2.4 Factor 4 – Traffic Exhaust Emissions

The fourth factor included large contributions for ethylbenzene (74%), m-, p-xylene (75%) and o-xylene (75%) as well as contributions for trichloroethene (47%) and toluene (45%). Three of the species are those that contribute to the BTEX summation variable, and are species that are characteristic of exhaust emissions (Bari et al., 2015) (McCarthy et al., 2013). Specifically, the presence of ethylbenzene in this factor suggests that the source is a long-range exhaust source, as explained in Section 5.1.3.1 (Edwards et al., 2001). This eliminates the possibility of interpreting this source as infiltration from the garage into the home, and indicates introduction of these species through the outdoor environment from window and door openings.

Again, this factor shows extremely high concentrations in house 19 over the three sampling days. Again, this traffic exhaust source could be transferred from the garage during work on the homeowner's motorcycles should they start them while working on them.

Figure 5-13: Factor 4 indoor microenvironment profile and corresponding concentrations

5.2.5 Factor 5 – Cleaners and Solvents

The fifth factor accounted for most of the measured benzaldehyde (84%), which is typically attributed to biogenic sources, however it can also be a sign of toluene oxidation. Additionally, other markers with contributions of more than 50% of its total mass include carbon disulphide (65%), styrene (65%), b-pinene (60%), isopropyl alcohol (58%), acetone (53%), carbon tetrachloride (53%), chloromethane (52%) and isoprene (51%). These are represented in Figure 5-14.

The combination of the other top species such as styrene, which is a common marker for fragrances and other solvents (Bari et al., 2015), and b-pinene can be representative of cleaners with a pine smell (Batterman et al., 2007). Bari et al. (2015) has also characterized species like carbon disulfide, carbon tetrachloride and chloromethane to solvent use and chlorination. From these characterizations, it was determined that factor five is representative of volatilization of paints, cleaners and solvents used within the home. The lower part of Figure 5-14 shows that while the concentrations are at relatively low levels the Factor is noticeable in many samples and houses.

Figure 5-14: Factor 5 indoor microenvironment profile and corresponding concentrations

5.2.6 Factor 6 – Organic/Wood Burning

The source species markers are very apparent in the factor profile shown in Figure 5-15. These include ethylene (66%), propene (67%) and 1,3-butadiene (66%), which are all species that can be linked to the burning of organic materials or biomass (World Health Organization, 2000) (Environment Canada, 2014) (Environment Canada, 2015). Considering the location of the sampling, this is likely linked to any wood burning fireplaces in the home, or any burning of food or oil that may occur during cooking events.

The distribution of the factor contribution graph is also indicative of cooking and burning events. The sporadic nature of the concentrations amongst samples aligns with the proposition that these events would be random cooking events with no observable pattern.

The daily diaries and baseline questionnaire was consulted for the one house with higher concentrations (house 27, days 1, 2 and 3), it was determined that the occupants in the home did fry with oil each of the three sampling days. The homeowners also have a wood stove in their home, and although it was not reported that wood burning occurred on those sampling days, the stove could have been used just prior to sampling beginning, leaving elevated levels of these compounds within the home.

Figure 5-15: Factor 6 indoor microenvironment profile and corresponding concentrations

5.3 Garage Microenvironment

Using the same process as in the previous two microenvironments based on Zhao et al.'s source apportionment work, (Zhao et al., 2004) it was predetermined that a 6- or 7-factor solution would be most accurate for the garage microenvironment. This was determined using the differences in slopes between the robust Q-values for 4- to 9-factor solutions as demonstrated in Figure 5-16 and Table 5-7.

Figure 5-16: Effect of changing the number of factors on Q-value in the Outdoor microenvironment

Table 5-7: Summary of Differences between Slopes for the Garage Microenvironment

Number of Factors	Q(Robust)	Slope(robust)	Difference
4 Factors	61696		
		7065	
5 Factors	54631		2381
		4684	
6 Factors	49947		625
		4059	
7 Factors	45888		574
		3485	
8 Factors	42403		282
		3203	
9 Factors	39200		

Running source apportionment for both 6- and 7-factor solutions resulted in a better, more interpretable solution using 6 factors. This was somewhat expected considering the indoor solution was resolved for 6 factors and the anticipation that the garage solution would likely have the same, if not fewer factors in a robust, interpretable solution. The results for this solution are summarized in Table 5-8 below. From the performance summary, the weak and bad species are displayed. As in the indoor microenvironment, the garage also required significant down-weighting of species to obtain a robust solution. Analysis started with down-weighting those species that were below an R^2 of 0.1. If a species below this threshold was considered a marker species, it was set as weak, however if it brought no little to no value to analysis, the species was marked as bad. Additionally, those samples that were entirely missing or samples that were identified as outliers in Section 4.6.4 were excluded from analysis.

Table 5-8: Performance Summary for the Garage Microenvironment

Input and Configuration				
Input Filename	RAGI_garage_PMFinput.xlsx			
C3	15			
Factors (<i>p</i>)	6			
Total Species	81			
Species – Weak 0.2 < S/N <2	37 - Acetylene, Propene, Acetaldehyde, Propane, Ethane, 1,3-Butadiene, Acrolein, Acetone, Butane, Isopropyl Alcohol, Isoprene, MEK (2-Butanone), 2-Methylbutane, Methyl Acetate, Carbon Disulfide, Benzene, Cyclohexane, Freon 22, Toluene, 1,2-Dichloroethane, MIBK, Heptane, Freon 134A, Chloroform, Freon 12, Nonane, Trichloroethene, p-Cymene, a-Pinene, b-Pinene, Camphene, Freon 11, 1,4-Dichlorobenzene, Undecane, Dodecane, Freon 114, Freon 113			
Species – Bad S/N < 0.2	20 – Methanol, Ethanol, Isobutane, Dichloromethane, Acetonitrile, 2-Methylpentane, Ethylacetate, Methyl-t-Butyl Ether, Methylcyclohexane, 3-Methylhexane, Benzaldehyde, 1-Octene, 2-Methylheptane, Butylacetate, Naphthalene, 1,1,1-Trichloroethane, 1,2-Dichlorobenzene, 1,3-Dichlorobenzene, Tetrachloroethene, Dibromochloromethane			
Excluded Samples	RAGI-10-1 RAGI-14-3 RAGI-19-1 RAGI-19-2	RAGI-19-3 RAGI-27-2 RAGI-27-3 RAGI-28-3	RAGI-30-1 RAGI-32-2 RAGI-36-1 RAGI-36-2	RAGI-38-1 RAGI-38-2 RAGI-38-3 RAGI-46-1
Stability				
Q_robust (range)	3194 (0.09)			
Q_true (range)	3194 (0.09)			
Q/Qexp	2.5			
Σd ²	<0.03			
Fit				
R ²	32 < R ² =0.50; 15 > R ² =0.90; median R ² = 0.45			
# residuals > 3	5 > 3			
High residuals	N/A			
Robustness				
Bootstrapping R	0.6			
Number of runs	100			
Bootstrapping factors mapping	Factor 1 = 96 / 1 / 0 / 0 / 1 / 1; 1 unmapped Factor 2 = 0 / 100 / 0 / 0 / 0 / 0; 0 unmapped Factor 3 = 0 / 2 / 92 / 0 / 0 / 2; 4 unmapped Factor 4 = 0 / 5 / 0 / 94 / 0 / 1; 0 unmapped Factor 5 = 0 / 3 / 1 / 0 / 90 / 1; 5 unmapped Factor 6 = 0 / 0 / 0 / 0 / 0 / 100; 0 unmapped			

The solution was found to have a robust and true range within 0.9 and a Q/Q_{exp} value of 2.5. The Q/Q_{exp} was higher than ideal, indicative of possibly requiring a higher-factor solution, however upon investigation, increasing the factors resulted in solutions that were either not as robust or very unstable and therefore the 6 factor solution was accepted. The sum of squared differences was less than 0.03 and there were only 5 species samples with a residual over $|3|$, all of which are from different species. Bootstrapping was conducted, resulting in a robust solution with over 90% bootstrap factors mapped to base factors. Table 5-9 summarizes the percent abundance that each species contributes to each factor and provides the typical location that the species may be observed in for further understanding of other potential sources should the species source typically not be in the garage.

Table 5-9: Summary of Marker Species for Each of the Evaluated Factors in the Garage microenvironment

Factor	Species ID	Species Name	Marker?	Contribution (%)	Found in Garage? (Y/N)	Type of Marker									
						Gas Exhaust	Diesel Exhaust	Gas Volatilization	Diesel Volatilization	Paints/ Cleaners/ Solvents	Degreasers/ Lubricants	Furniture/ Wood	Personal Care	Biogenic	Other
1	S017	1-Butene	Y	43%		X	X								
	S019	t-2-Butene	Y	72%	Y			X							
	S023	Butane	Y	55%	Y					X					
	S033	1-Pentene	Y	60%		X									
	S035	t-2-Pentene	Y	68%	Y			X							
	S045	Pentane	Y	55%	Y	X	X	X		X					
	S073	2,2-Dimethylbutane	Y	55%	Y		X	X							
	S074	2,3-Dimethylbutane	Y	53%				X							
	S077	Hexane	Y	44%	Y	X	X	X	X			X			
	S104	2-Methylhexane	Y	51%		X									
2	S001	Acetylene	Y	64%	Y	X	X	X							
	S002	Ethylene	Y	60%	Y	X	X								LPG vehicle;petrochem
	S003	Ethane	Y	56%	Y	X		X	X						LPG vehicle;petrochem
	S007	Propene	Y	61%	Y		X								petro-chem
	S012	Chloromethane	N	51%											
	S015	1,3-Butadiene	Y	58%		X	X								
	S044	2-Methylbutane	Y	51%		X									
	S108	Freon 134A	Y	65%											refrigerant
	S149	Freon 12	Y	56%											refrigerant
	S172	Freon 11	Y	62%						X					refrigerant

	S180	Carbon tetrachloride	Y	56%						X					global background
	S189	Freon 114	Y	57%											refrigerant
	S193	Freon 113	Y	57%											refrigerant
3	S016	Acrolein	Y	50%											gas stove, wild fires
	S020	Acetone	Y	46%						X			X		
	S030	Isoprene	Y	52%	Y	X	X			X				X	
	S046	Methyl Acetate	N	67%											
	S050	Carbon Disulfide	N	42%											
	S110	Styrene	Y	71%						X		X			printer ink
	S140	Chloroform	Y	62%						X					water treatment
	S168	a-Pinene	Y	73%	Y					X					cleaner - pine smell
	S169	b-Pinene	Y	83%	Y					X					cleaner - pine smell
	S171	Camphene	Y	52%	Y					X					cleaner
4	S188	Dodecane	Y	65%	Y		X	X	X	X	X				
	S141	1,2,3-Trimethylbenzene	Y	41%		X	X								
	S155	Nonane	Y	63%	Y			X							
	S176	Decane	Y	74%	Y		X	X	X	X					
5	S183	Undecane	Y	65%	Y		X	X	X	X					
	S165	p-cymene	Y	31%		X				X					solvent
	S168	a-Pinene	Y	20%	Y					X					cleaner - pine smell
	S170	Limonene	Y	85%	Y					X					cleaner - citrus smell
6	S051	Benzene	Y	37%	Y	X	X	X	X						
	S063	Cyclohexane	Y	31%	Y			X	X						
	S077	Hexane	Y	35%	Y	X	X	X	X			X			
	S083	Toluene	Y	49%	Y	X	X	X	X		X				BTEX
	S104	2-Methylhexane	Y	33%		X									
	S106	Heptane	Y	43%	Y	X		X							
	S112	Ethylbenzene	Y	57%	Y	X	X	X	X						BTEX
	S113	m-, p-Xylene	Y	60%	Y	X	X	X	X		X				BTEX

S114	o-Xylene	Y	61%	Y	X	X	X	X		X				BTEX
S136	Octane	Y	36%	Y	X		X							Evap > volatilization
S141	1,2,3-Trimethylbenzene	Y	36%		X	X								
S142	1,2,4-Trimethylbenzene	Y	48%		X	X	X	X	X					
S143	1,3,5-Trimethylbenzene	Y	46%		X	X								
S145	3-Ethyltoluene	Y	52%		X	X								
S146	4-Ethyltoluene	Y	52%		X									

5.3.1 Factor 1 – Fuel Evaporation

The Factor 1 profile and contribution graphs are shown in Figure 5-17 below. Species contributing over 40% of their total mass to the factor were considered as markers. Some of these species included trans-2-butene and trans-2-pentene, 1-pentene, 2,2-dimethylbutane, pentane and butane. Based on the strong presence of these species and previous source apportionment research conducted by Bari et al. (2015) and Watson et al. (2001) the factor would likely be representative of fuel evaporation. This is consistent with the location of sampling, considering the typical garage houses various fuels and fuel consumption equipment. The Factor showed noticeably higher concentrations in 8 samples from 3 houses.

Figure 5-17: Factor 1 garage microenvironment profile and corresponding concentrations

Figure 5-18: Factor Concentrations from Gasoline Evaporation factor in Indoor Microenvironment analysis

Upon comparison to the indoor microenvironment analysis, similar peaks are observed in both factor contribution graphs as demonstrated in Figure 5-18. As expected, the concentrations in house 37 in the garage are higher than the concentrations observed in the home. House 19 oddly showed higher contributions in the home rather than the garage and unfortunately the daily diary did not give explicit reasoning for the higher indoor concentrations.

5.3.2 Factor 2 – Outdoor sources / Global Background

The second factor consisted largely of halogenated compounds including compounds such as Freon 134A, 12, 11, 114 and 113 and carbon tetrachloride, which are typically interpreted as global background species due to the persistent nature of the compounds. Furthermore, species representative of bi-products of the petrochemical industry such as ethylene, ethane and propene were observed (Bari et al., 2015) (McCarthy et al., 2013). The factor profile and factor concentration graph demonstrating these contributions is shown in Figure 5-19.

Figure 5-19: Factor 2 garage microenvironment profile and corresponding concentrations

Similar species were observed in the outdoor microenvironment as well, noted in Section 5.1.2. This supports the weak correlation observed between the two microenvironments mentioned in Section 4.6.2. Similar to the global background factor in the outdoor analysis, the factor concentrations show a fairly consistent contribution for this factor amongst almost all samples except for the few samples yielding no contribution with no real explanation. From this reasoning, this factor was determined to represent infiltration from the outdoor microenvironment through un-insulated and leaky garages.

5.3.3 Factor 3 – Cleaners / Solvents

Factor three source profiles and factor concentrations are shown in Figure 5-20.

The most notable species in this factor profile include several species from the terpenes groups including α -, β -pinene, styrene, isoprene and camphene in order of contribution. Pinenes are typically associated with pine smells of cleaners, and the remaining are also associated with the volatilization of cleaners (Batterman et al. 2007) (Bari et al., 2015). The presence of dodecane, chloroform and acetone is also indicative of industrial sources (Bari et al., 2015). These cleaners likely could be emitted in garages through storage and volatilization through the containers, as well as perhaps through various cleaning activities conducted in the garage.

The daily diary for house 24 was consulted. This indicated that there were paints and solvents stored in the garage, however, information regarding the amount that was stored was unavailable.

Figure 5-20: Factor 3 garage microenvironment profile and corresponding concentrations

5.3.4 Factor 4 – Diesel Exhaust Emissions

Factor four markers include 1,2,3-trimethylbenzene (41%), nonane (63%), decane (74%) and undecane (65%). These contributing species are shown in Figure 5-21.

These heavy alkanes and aromatic are known markers for diesel exhaust emissions. Considering the location of the sampling is the garage, mobile sources may be strong enough to differentiate between the two fuel types, unlike in the outdoor and indoor microenvironments. Unfortunately, the study baseline questionnaire did not include consideration for the type of fuel used in mobile sources at each home, however should this information have been made available, it would have been possible to corroborate this conclusion with the presence of a diesel source in these homes, specifically.

Figure 5-21: Factor 4 garage microenvironment profile and corresponding concentrations

5.3.5 Factor 5 – Air fresheners / Deodorizers

The fifth factor is largely limited to terpenes as marker species where 85% of limonene total concentration is identified in this factor. Following, 31% of p-cymene and 20% of α-pinene is resolved to the factor. This factor profile is shown in Figure 5-22 below.

Considering the short list of species that contribute to this factor, unlike Factor 3, which contained some terpenes as well as other marker species, it was determined that this factor would be resolved strictly to any air fresheners or deodorizers either used or stored within the garage or infiltrating from the home to the garage.

The high concentration contributor in the Factor Concentrations graph was identified as house 24-1 and house 24-2. It was determined that one of the homeowners would go into the garage to smoke a cigarette. The diary asks whether anyone used air fresheners in the house over the previous 24 hours, however it could be that this homeowner sprayed an air freshener in the garage following this to mask the smell, leading to the higher concentrations observed and the lack of reporting on the daily diary due to the specificity of the location.

Figure 5-22: Factor 5 garage microenvironment profile and corresponding concentrations

5.3.6 Factor 6 – Gasoline Exhaust Emissions

The profile and source concentrations are shown in Figure 5-23 for factor 6. Factor 6 was another very apparent source profile, based on the high contributing species markers. All four BTEX species were present in this factor, where xylenes contribute approximately 60% of their total mass to this factor. The presence of BTEX indicates that the factor must be related to fuel. The presence of 3-,4-ethyltoluene is indicative of combustion emissions rather than volatilization (Bari et al., 2015). In combination with the resolution of Factor 1 for fuel volatilization, it was determined that this factor is representative of volatilization of those fuels stored within the garage.

The daily diary for the three samples in house 41, as identified in the Factor Concentrations graph in Figure 5-23, indicated that the car was pulled out and returned more than once, which was more than the average home. This could contribute to the slightly elevated factor concentrations in this home for gasoline exhaust emissions.

Figure 5-23: Factor 6 garage microenvironment profile and corresponding concentrations

5.3.6.1 *BTEX Ratios*

Similar to the outdoor and indoor microenvironments, the toluene-to-benzene and m-, p-xylene to ethylbenzene ratio was calculated for the garage BTEX concentrations. The mean and median for T/B was calculated to be 6.6 and 5.9 whereas the X/E ratio was 3.4 and 3.3. Although the garage was expected to contain traffic/exhaust emissions, it is noted that this higher ratio indicates larger influence from industry and solvent use. This is likely attributed to the storage of industrial solvents in the microenvironment. The X/E ratio indicates that the vaporization has aged, but not to the extent that the outdoor microenvironment has.

5.4 Source Apportionment Discussion

One of the most recently published work by Bari et al. in 2015 used source apportionment for samples obtained in homes and outdoors in Edmonton, Canada. It was determined that more than 70% of total indoor VOCs were attributed to indoor sources including household products (44%), combustion processes and environmental tobacco smoke (10.5%), deodorizers (8.4%) and off-gassing of building materials (5.9%). Outdoor sources included oil and gas industry, traffic emissions, background and biogenic emissions (Bari et al., 2015).

McCarthy et al. published their source apportionment work in 2013, which was also conducted in Edmonton, Canada. PMF was used to resolve eleven ambient factors. These included gasoline and diesel combustion, industrial sources (evaporative, feedstock,

gasoline production/storage, industrial chemical), mixed mobile and industrial (gasoline evaporative, fugitive butane), biogenic, natural gas and global background pollution.

Yurdakul, Civan and Tuncel also applied ambient source apportionment in suburban Ankara, Turkey in 2013. Four sources were resolved including gasoline exhaust, solvent evaporation, diesel emission and laboratory sources (Yurdakul et al., 2013). For this study, the average ambient winter T/B ratio is 2.7 and the average ambient X/E ratio is 2.5 (Yurdakul et al., 2013). These values are comparable to those found in RAGI ambient sampling where the average ratios were 1.4 and 2.6, respectively.

In 2011, Guo published their work on source apportionment in Hong Kong homes resulting in a list of indoor sources including off-gassing of building materials (76.5%), room freshener (8%), household products (6%), mothballs (5%) and painted wood products (4%) (Guo, 2011).

Lastly, Anderson et al. published their personal exposure source apportionment in 2002. They reported six significant sources, which include gasoline vapours/automobile exhaust, dry-cleaning chemicals, tap water, deodorizers/mothballs, and building materials/carpeting (Anderson et al., 2002). These sources can be connected largely to those the population is exposed to indoors, considering the extent to which daily life is spent in homes.

The source apportionment data collected from the RAGI study consults and largely overlaps these studies and many others. Many factors, especially those solved for in outdoor microenvironments had similar profile combinations due to the influence of mobile emissions and industry. Source apportionment in the Ottawa area resulted in six outdoor

factors including wood/charcoal combustion, global background, traffic exhaust emissions, industrial and mobile evaporative emissions, petrochemical and other industrial sources as well as solvent use in industrial processes.

Indoor studies such as those conducted by Bari and McCarthy tended to resolve for a much larger suite of factors, whereas a robust solution for source apportionment in the RAGI indoor microenvironment was found in a 6-factor solution. A slightly higher factor solution was indeed expected, however, considering the goodness of fit parameter (Q-values) over the range of solutions and the interpretability of the 6-factor solution in comparison to the extensively explored higher-factor solutions, the 6-factor solution was maintained. The indoor sources were categorized to environmental tobacco smoke, diesel evaporation, floor and wall coverings, traffic exhaust emissions, cleaners and solvents and infiltration from the oil/gas industry and storage.

As mentioned, there were very few studies considering attached garages as sources of toxic VOCs. Even fewer consider source apportionment of attached garages. Through extensive searching, only Graham et al. combined source apportionment (CMB) with an attached garage study. Even so, results reported only the percent contributions during hot-soak and cold start emissions from the garage with no mention of any other sources, solidifying the need for more source apportionment research comparing the impact that attached garages have on the indoor environment.

6 Conclusions and Recommendations

The outcome of this thesis intended to build on the significant work that Health Canada was conducting to examine interventions to reduce the impact that attached garages have on the air inside homes. Using the concentration data, source apportionment modelling was used to resolve sources that contribute to the home, garage and ambient microenvironments, thereby providing insight to air exchange and VOC infiltration between these microenvironments. This source apportionment was used in combination with statistical analysis, verifying the statistical significance of the relationships between sampling locations. Using source apportionment modelling, it was also possible to provide insight to the major source types that contribute to VOC concentrations in homes and ambient air in Ottawa, Canada.

The literature review showed that although the presence of elevated VOC concentrations in homes has been addressed and studies have sampled within homes, few studies have considered sampling and quantifying VOC concentrations in attached garages. Even fewer studies have conducted source apportionment on homes with attached garages, investigating the influence that attached garages have on the indoor concentrations.

Statistical analysis of the sample data used four general summation variables as well as the top ten species in each microenvironment to characterize the behaviour of species under various conditions. The four summation variables include TVOC, SUM81VOC, SUM15CEPA and BTEX which are the total VOC suite, the sub-suite of 81 species after screening criteria were applied, the sub-suite of 15 species identified as toxic under the *Canadian Environmental Protection Act* and the sub-suite of 4 species representative of

fuels and exhaust emissions (benzene, toluene, ethylbenzene and m-, o-, p-xylenes). Ethanol and methanol were top contributors across all microenvironments, contributing between 24% and 57% of the total concentration.

Comparison of the summary statistics found in Ottawa samples to other similar studies revealed similar sum of indoor medians for Ottawa, Edmonton and Regina studies. The Windsor study was approximately 80% of the concentrations Ottawa homes. Ottawa, Edmonton and Windsor studies were very similar in outdoor medians as well with the Edmonton outdoor concentrations approximately 140% that of the Outdoor ambient concentrations. These comparisons provided context for further analysis. Summary statistics between microenvironments for each summation variable were also considered providing insight to the magnitude of concentrations in each microenvironment. Patterns like high concentrations of BTEX compounds in the garage, and much larger concentrations in garage and indoor locations compared to outdoor microenvironments were observed. To solidify the extent of interaction between microenvironments, the degree of correlation between microenvironments were considered. This revealed correlation of BTEX compounds between garage and indoor microenvironments and TVOC/SUM81 compounds showed a weak correlation of 0.27 between garage and outdoor microenvironments. This correlation data provides insight to not only how air infiltrates into microenvironments, but also how microenvironments with high contributing sources can impact other microenvironments. For example, the influence that BTEX sources within the garage have on the concentrations found indoors. Microenvironment ratios also confirmed and influenced these relationships conclusions between microenvironments. A very high G/O for BTEX compounds indicates that the concentrations found in the garage

are much higher than those dispersed in ambient air, however the lower ratio of 4.1 for G/I BTEX compounds coupled with the weak correlation noted between those microenvironments likely indicates that the higher concentrations found in the garage infiltrate the home, contributing to the concentration observed indoors.

A comprehensive outlier analysis using time series and box plots revealed a series of samples that were considered outliers from the typical concentration values. Identifying samples that were beyond three times the interquartile range proved most effective for considering those species from analysis. Summation variables TVOC and SUM81 were considered for this analysis but yielded identical results. Outdoor and indoor microenvironments identified two samples for exclusion consideration where ten samples were identified as outliers in the garage microenvironment. This represented less than ten percent of the total samples.

Additionally, source apportionment modelling resulted in the resolution of 6 factors in the sampled outdoor microenvironment, 6 factors in the indoor sampling location and 6 factors in the garage sampling location based on the high contributing species in each factor profile.

The outdoor microenvironment factors were interpreted to include:

1. Wood/Charcoal combustion – acetaldehyde and acrolein
2. Global background – 1,2-dichloroethane, chloromethane, 1,1,1-trichloroethane, carbon tetrachloride and Freon 11, 12, 113 and 114

3. Traffic exhaust emissions – 1,2,3-trimethylbenzene, 1,2,4-trimethylbenzene, 1,2,5-trimethylbenzene, 3- and 4-ethyltoluene, naphthalene and undecane
4. Industrial and mobile fuel evaporative emissions - trans-2-butene, trans-2-pentene, butane and isobutane
5. Petrochemical and other industrial sources – 3-methylhexane, 1,3-butadiene, acetylene, propene, isoprene, toluene, methylcyclohexane, heptane, 2-methylheptane, octane, nonane and tetrachloroethene
6. Solvent use in Industrial Processes – methyl acetate, ethyl acetate and butyl acetate

The indoor microenvironment factors were interpreted to include:

1. Environmental tobacco smoke – octane, benzene, 3-, 4-ethyltoluene and hexane
2. Gasoline evaporation – trans-2-butene, trans-2-pentene, butane, methyl acetate, 1-pentene
3. Floor and wall coverings - C9- to C12-alkanes, trimethylbenzene isomers, n-butylbenzene, n-Propylbenzene, ethyltoluene isomers and octane
4. Traffic exhaust emissions – ethylbenzene, m-, p-xylene, o-xylene, trichloroethene and toluene
5. Cleaners / solvents – benzaldehyde, carbon disulphide, styrene, b-pinene, isopropyl alcohol, acetone, carbon tetrachloride, chloromethane and isoprene
6. Organic/Wood Burning - m – ethylene, propene and 1,3-butadiene

And last, the garage microenvironment factors were interpreted to include:

1. Fuel evaporation - trans-2-butene and trans-2-pentene, 1-pentene, 2,2-dimethylbutane, pentane and butane
2. Outdoor sources / global background - Freon 134A, 12, 11, 114 and 113 and carbon tetrachloride
3. Cleaners / solvents - a-, b-pinene, styrene, isoprene and camphene
4. Diesel exhaust emissions - 1,2,3-trimethylbenzene, nonane, decane and undecane
5. Air fresheners / deodorizers – limonene, p-cymene and a-pinene
6. Gasoline exhaust emissions – benzene, toluene, ethyltoluene, m-, p- and o-xylenes, 3- and 4-ethyltoluene

The resolved factors were compared to those found in studies in similar locations including those found in work published by Bari et al. and McCarthy et al. in Edmonton, Canada; Yurdakil, Civan and Tuncel in Ankara, Turkey; Guo in Hong Kong, China; and Anderson et al. in New Jersey and California. Unfortunately, as mentioned, there is very little work published that compares the garage to indoor or outdoor microenvironments, let alone those that study source apportionment of homes with attached garages. The abovementioned studies had several factors, which were similar in species markers, allowing for verification of the resolved factors from this research.

Conducting this research revealed the need for more literature that examines sources within homes with attached garages, especially since the significant impact that garages have on home air quality has already been established. The overlap of garage and indoor apportioned factors, including fuel evaporation and traffic exhaust emissions indicate the exchange of air between the microenvironments. The identification of factors limited to

activities/storage of items in separate microenvironments, such as floor/wall coverings found indoors and global background outdoors helps confirm the legitimacy of the source apportionment work.

Further research could include conducting a parallel source apportionment investigation using the post-intervention concentration data, as mentioned in Health Canada study outline in Section 3.1. The results of this source apportionment could be used to compare to the current pre-intervention results to determine the effectiveness of the interventions on the movement of air between microenvironments and thereby improving human health indoors.

Additionally, having similar studies conducted in homes in other locations and conducting source apportionment with this data would help validate the factors found in this study. The source apportionment work for this study required many manipulations of factor numbers, and sample / species inclusion for a robust result. Having data to compare to these results would confirm the legitimacy of the input selections.

Last, including temporal variation of the study could add another consideration to the scope of the research. The current study was limited to winter data however conducting the study in both winter and summer could provide another dimension to understanding how air moves from the garage to the home during hotter temperatures.

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8 Appendix A: Example of Baseline Questionnaire

BASELINE QUESTIONNAIRE – WINTER 2013 & 2014

Residential Attached Garage Intervention (RAGI)

Study in Ottawa, Ontario

Participant ID: RAGI - _____

Technician Name: _____

Date (yyyy / mm/ dd): _____

Technician instructions: For all text responses, enter -9 if the answer is “*I prefer not to say*” and -7 if the answer is “*I don’t know*”.

* Please, identify which room is considered as the monitored room:
_____.

The purpose of this questionnaire is to obtain information on study participants and their home. We are asking the same questions to each participant in the study. The questions cover personal household information and general characteristics of the home. All information will be kept confidential. Completion of all questions is mandatory. However, if there are questions that you do not feel comfortable answering, you can choose “I prefer not to say”.

Q1: For the primary homeowner(s), please complete the following table.

Occupation	Highest grade or level of education completed
1. _____ ☐ I prefer not to say	☐ No schooling ☐ High School ☐ CEGEP or College ☐ University ☐ Other: _____ ☐ I prefer not to say
2. _____ ☐ I prefer not to say	☐ No schooling ☐ High School ☐ CEGEP or College ☐ University ☐ Other: _____ ☐ I prefer not to say

Q2. What was your total household income last year? In which of the following ranges did your **TOTAL HOUSEHOLD INCOME** fall for the last year? Include all income, before taxes and deductions.

☐ Less than \$35,000	☐ \$35,000 to \$80,000
☐ \$80,000 to \$120,000	☐ More than \$120,000
☐ Don’t know	☐ I prefer not to say

Q3. In what year was your home built? _____

☐ I prefer not to say

☐ I don't know

Q4. Please, indicate the geographical orientation of the front of your home.

☐ North

☐ East

☐ West

☐ South

☐ North-East

☐ South-West

☐ North-West

☐ South-East

☐ I prefer not to say

☐ I don't know

Q5. How many people (including children) typically live inside your home?

☐ 1

☐ 3

☐ 5

☐ 2

☐ 4

☐ 6 or more

☐ I prefer not to say

Q6. What is your primary water source in your home?

☐ Well

☐ Other: _____

☐ City

☐ I prefer not to say

Q7. Is your home located within approximately 90 meters or 1 block of a volatile organic compounds source such as a chemical manufacturer, a gas station, a laundromat, a dry cleaner, a landfill or an auto mechanic garage?

☐ No

☐ Yes. Please specify:

☐ I prefer not to say

Q8. What is the main type of heating system in your house and what is the energy source used for this heating system? *Complete the table.*

Heating system	Response	Energy source
Forced air furnace	☐ No ☐ Yes ☐ I prefer not to say	☐ Electric ☐ Natural gas ☐ Propane ☐ Oil ☐ Other: please specify: _____ ☐ I prefer not to say
Radiators (steam or hot water)	☐ No ☐ Yes ☐ I prefer not to say	☐ Electric ☐ Natural gas ☐ Propane ☐ Oil ☐ Other: please specify: _____ ☐ I prefer not to say

Radiant floor or Ceiling panels	☐ No ☐ Yes ☐ I prefer not to say	☐ Electric ☐ Natural gas ☐ Propane ☐ Oil ☐ Other: please specify: <hr/> ☐ I prefer not to say
Baseboard heaters	☐ No ☐ Yes ☐ I prefer not to say	☐ Electric ☐ Other: please specify: <hr/> ☐ I prefer not to say

Q9. *Complete the table.* Please indicate whether you have any of the following natural gas, propane or oil fuelled items in your home and how frequently you typically use these items in winter. Please also indicate whether the item has a pilot light and the type of fuel.

Item	Response	Do you typically use this item in winter?	Pilot Light	Type of Fuel
Gas Stove	☐ No ☐ Yes ☐ I prefer not to say	☐ No ☐ Yes ☐ I prefer not to say	☐ No ☐ Yes ☐ I prefer not to say	☐ Natural Gas ☐ Propane ☐ I prefer not to say
Gas Fireplace	☐ No ☐ Yes ☐ I prefer not to say	☐ No ☐ Yes ☐ I prefer not to say	☐ No ☐ Yes ☐ I prefer not to say	☐ Natural Gas ☐ Propane ☐ I prefer not to say
Gas Clothes Dryer	☐ No ☐ Yes ☐ I prefer not to say	☐ No ☐ Yes ☐ I prefer not to say	☐ No ☐ Yes ☐ I prefer not to say	☐ Natural Gas ☐ Propane ☐ I prefer not to say
Gas Space Heater	☐ No ☐ Yes ☐ I prefer not to say	☐ No ☐ Yes ☐ I prefer not to say	☐ No ☐ Yes ☐ I prefer not to say	☐ Natural Gas ☐ Propane ☐ I prefer not to say
Water Heater	☐ No ☐ Yes ☐ I prefer not to say		☐ No ☐ Yes ☐ I prefer not to say	☐ Natural Gas ☐ Propane ☐ Oil ☐ I prefer not to say
Other, please specify: _____	☐ No ☐ Yes ☐ I prefer not to say	☐ No ☐ Yes ☐ I prefer not to say	☐ No ☐ Yes ☐ I prefer not to say	☐ Natural Gas ☐ Propane ☐ Oil

			☐ I don't know	☐ I prefer not to say
--	--	--	---------------------------------------	--

Q10. *Complete the table.* Please indicate whether you have any of the following wood fuelled items in your home and if you typically use these items in winter. *Check all that apply.*

Item	Response	Do you typically use this item in winter?
Wood Fireplace	☐ No ☐ Yes ☐ I prefer not to say	☐ No ☐ Yes ☐ I prefer not to say
Wood Stove	☐ No ☐ Yes ☐ I prefer not to say	☐ No ☐ Yes ☐ I prefer not to say
Pellet Stove	☐ No ☐ Yes ☐ I prefer not to say	☐ No ☐ Yes ☐ I prefer not to say

Q11. *Complete the table.* Please indicate whether you have any of the following items that influence humidity in your home and if you typically use these items in winter. *Check all that apply.*

Item	Response	Do you typically use this item in winter?
Humidifier on Furnace	☐ No ☐ Yes ☐ I prefer not to say	☐ No ☐ Yes ☐ I prefer not to say
Room humidifier	☐ No ☐ Yes ☐ I prefer not to say	☐ No ☐ Yes ☐ I prefer not to say
Stand-alone dehumidifier	☐ No ☐ Yes ☐ I prefer not to say	☐ No ☐ Yes ☐ I prefer not to say

Q12. *Complete the table.* Please indicate whether you have any of the following **home ventilation systems** in your home and indicate how it is controlled. *Check all that apply.*

Home ventilation system	Response	Control
Occasional use of kitchen fan	☐ No ☐ Yes ☐ Inoperable ☐ I prefer not to say	

Occasional use of bathroom fan	☐ No ☐ Yes ☐ Inoperable ☐ I prefer not to say	☐ Off/ on switch ☐ Timer ☐ Humidity activated ☐ Combined light and fan switch ☐ I prefer not to say
Bathroom fan controlled by ventilation switch in living/dining/family room	☐ No ☐ Yes ☐ Inoperable ☐ I prefer not to say	
Central Exhaust	☐ No ☐ Yes ☐ Inoperable ☐ I prefer not to say	
Heat recovery ventilation (HRV)	☐ No ☐ Yes ☐ Inoperable ☐ I prefer not to say	☐ Off/ on switch ☐ Timer ☐ Continuous ☐ Temperature or humidity activated ☐ I prefer not to say
Other: _____ _____ _____	☐ No ☐ Yes ☐ Inoperable ☐ I prefer not to say	☐ Off/ on switch ☐ Timer ☐ Continuous ☐ Temperature or humidity activated ☐ I prefer not to say

Q13. Do you have a kitchen fan?

- ☐ No
☐ Yes
☐ I prefer not to say

If yes, does your kitchen fan exhaust to the outdoors? *

- ☐ No
☐ Yes
☐ I prefer not to say

* *Fan with exhaust to the outdoors: extracts air or excess moisture from the interior of a home to the outside.*

Q14. How many bathroom fans do you have?

- ☐ 0
☐ 1
☐ 2
☐ 3
☐ 4 or more
☐ I prefer not to say

Q15. How many bathroom fans do you have that exhaust to the outdoors?

- ☐ 0
☐ 1
☐ 2
☐ 3
☐ 4 or more
☐ Don't know
☐ I prefer not to say

Q16. Do you have carpets (wall-to-wall or of a significant size) or area rugs in your home?

- ☐ No
☐ Yes
☐ I prefer not to say

If yes, where (bedroom, bathroom, kitchen, living room, dining room, family room, basement, etc.) and when were they installed? *Complete the table.*

Room	Date of installation
1. _____ ☐ I prefer not to say	____ / ____ mm / yyyy ☐ I prefer not to say
2. _____ ☐ I prefer not to say	____ / ____ mm / yyyy ☐ I prefer not to say
Room	Date of installation
3. _____ ☐ I prefer not to say	____ / ____ mm / yyyy ☐ I prefer not to say
4. _____ ☐ I prefer not to say	____ / ____ mm / yyyy ☐ I prefer not to say
5. _____ ☐ I prefer not to say	____ / ____ mm / yyyy ☐ I prefer not to say
6. _____ ☐ I prefer not to say	____ / ____ mm / yyyy ☐ I prefer not to say
7. _____ ☐ I prefer not to say	____ / ____ mm / yyyy ☐ I prefer not to say
8. _____ ☐ I prefer not to say	____ / ____ mm / yyyy ☐ I prefer not to say
Other, please specify: _____	____ / ____ mm / yyyy ☐ I prefer not to say

Q17. Have you done any painting or refinishing of walls, floors, or built in cabinets, or any renovations using sealants or glues within the last 3 months?

- ☐ No
☐ I prefer not to say
☐ Yes, please specify the number of locations within the home _____. *Complete the table.*

Room	Monitored room	Type of work	Product used	Work completed
1. _____ _____ _____ ☐ I prefer not to say	☐ Yes ☐ No ☐ I prefer not to say	☐ Painting ☐ Finishing ☐ Sealants / glues ☐ Other: _____ ☐ I prefer not to say	☐ Water based (not low VOC) ☐ Oil based (not low VOC) ☐ Low VOC ☐ No VOC ☐ Other: _____ ☐ I prefer not to say	____ / ____ mm / yyyy ☐ I prefer not to say
2. _____	☐ Yes ☐ No ☐ I prefer not to say	☐ Painting ☐ Finishing ☐ Sealants / glues	☐ Water based (not low VOC) ☐ Oil based (not low VOC) ☐ Low VOC	____ / ____ mm / yyyy

_____ _____ ☐ I prefer not to say		☐ Other: _____ _____ ☐ I prefer not to say	☐ No VOC ☐ Other: _____ ☐ I prefer not to say	☐ I prefer not to say
Room	Monitored room	Type of work	Product used	Work completed
3. _____ _____ _____ ☐ I prefer not to say	☐ Yes ☐ No ☐ I prefer not to say	☐ Painting ☐ Finishing ☐ Sealants / glues ☐ Other: _____ _____ ☐ I prefer not to say	☐ Water based (not low VOC) ☐ Oil based (not low VOC) ☐ Low VOC ☐ No VOC ☐ Other: _____ ☐ I prefer not to say	_____ / _____ mm / yyyy ☐ I prefer not to say
4. _____ _____ _____ ☐ I prefer not to say	☐ Yes ☐ No ☐ I prefer not to say	☐ Painting ☐ Finishing ☐ Sealants / glues ☐ Other: _____ _____ ☐ I prefer not to say	☐ Water based (not low VOC) ☐ Oil based (not low VOC) ☐ Low VOC ☐ No VOC ☐ Other: _____ ☐ I prefer not to say	_____ / _____ mm / yyyy ☐ I prefer not to say
5. _____ _____ _____ ☐ I prefer not to say	☐ Yes ☐ No ☐ I prefer not to say	☐ Painting ☐ Finishing ☐ Sealants / glues ☐ Other: _____ _____ ☐ I prefer not to say	☐ Water based (not low VOC) ☐ Oil based (not low VOC) ☐ Low VOC ☐ No VOC ☐ Other: _____ ☐ I prefer not to say	_____ / _____ mm / yyyy ☐ I prefer not to say
6. _____ _____ _____ ☐ I prefer not to say	☐ Yes ☐ No ☐ I prefer not to say	☐ Painting ☐ Finishing ☐ Sealants / glues ☐ Other: _____ _____ ☐ I prefer not to say	☐ Water based (not low VOC) ☐ Oil based (not low VOC) ☐ Low VOC ☐ No VOC ☐ Other: _____ ☐ I prefer not to say	_____ / _____ mm / yyyy ☐ I prefer not to say
7. _____ _____ _____ ☐ I prefer not to say	☐ Yes ☐ No ☐ I prefer not to say	☐ Painting ☐ Finishing ☐ Sealants / glues ☐ Other: _____ _____ ☐ I prefer not to say	☐ Water based (not low VOC) ☐ Oil based (not low VOC) ☐ Low VOC ☐ No VOC ☐ Other: _____ ☐ I prefer not to say	_____ / _____ mm / yyyy ☐ I prefer not to say
8. _____ _____ _____ ☐ I prefer not to say	☐ Yes ☐ No ☐ I prefer not to say	☐ Painting ☐ Finishing ☐ Sealants / glues ☐ Other: _____ _____ ☐ I prefer not to say	☐ Water based (not low VOC) ☐ Oil based (not low VOC) ☐ Low VOC ☐ No VOC ☐ Other: _____ ☐ I prefer not to say	_____ / _____ mm / yyyy ☐ I prefer not to say

Room	Monitored room	Type of work	Product used	Work completed
9. _____ _____ — ☐ I prefer not to say	☐ Yes ☐ No ☐ I prefer not to say	☐ Painting ☐ Finishing ☐ Sealants / glues ☐ Other: _____ _____ ☐ I prefer not to say	☐ Water based (not low VOC) ☐ Oil based (not low VOC) ☐ Low VOC ☐ No VOC ☐ Other: _____ ☐ I prefer not to say	_____/_____ mm / yyyy ☐ I prefer not to say
10. _____ _____ — ☐ I prefer not to say	☐ Yes ☐ No ☐ I prefer not to say	☐ Painting ☐ Finishing ☐ Sealants / glues ☐ Other: _____ _____ ☐ I prefer not to say	☐ Water based (not low VOC) ☐ Oil based (not low VOC) ☐ Low VOC ☐ No VOC ☐ Other: _____ ☐ I prefer not to say	_____/_____ mm / yyyy ☐ I prefer not to say

Q18. Have any renovations/updates been done to your home since it was built that would affect the tightness of your home? *Check all that apply.*

☐ No	☐ Upgrade wall insulation
☐ Upgrade windows	☐ Upgrade ceiling/attic insulation
☐ Housewrap	☐ I prefer not to say
☐ Other, please specify:	

Q19. Have you had any new construction or renovations to your home during the last 3 months that involved plywood or particle board, including cabinets, or any other pressed wood products?

- ☐ No
☐ Yes
☐ I prefer not to say

Q20. Have you bought any new furniture within the last 3 months?

- ☐ No
☐ Yes, please specify how many: _____. If yes, *complete the table* (see the next page).
☐ I prefer not to say

Complete the table if you have you bought any new furniture within the last 3 months.

Type of furniture	Material (<i>Check all that apply</i>)	Room	Monitored room	Date installed
1. _____ _____ _____	☐ Leather ☐ Fabric ☐ Melamine ☐ Particleboard ☐ Wood ☐ Plywood	_____	☐ Yes ☐ No	_____/_____ mm / yyyy

	☐ MDF* ☐ I prefer not to say ☐ Other: _____	☐ I prefer not to say	☐ I prefer not to say	☐ I prefer not to say
2. _____ _____ _____	☐ Leather ☐ Fabric ☐ Melamine ☐ Particleboard ☐ Wood ☐ Plywood ☐ MDF* ☐ I prefer not to say ☐ Other: _____	_____ _____ ☐ I prefer not to say	☐ Yes ☐ No ☐ I prefer not to say	_____/_____ mm / yyyy ☐ I prefer not to say
3. _____ _____ _____	☐ Leather ☐ Fabric ☐ Melamine ☐ Particleboard ☐ Wood ☐ Plywood ☐ MDF* ☐ I prefer not to say ☐ Other: _____	_____ _____ ☐ I prefer not to say	☐ Yes ☐ No ☐ I prefer not to say	_____/_____ mm / yyyy ☐ I prefer not to say
4. _____ _____ _____	☐ Leather ☐ Fabric ☐ Melamine ☐ Particleboard ☐ Wood ☐ Plywood ☐ MDF* ☐ I prefer not to say ☐ Other: _____	_____ _____ ☐ I prefer not to say	☐ Yes ☐ No ☐ I prefer not to say	_____/_____ mm / yyyy ☐ I prefer not to say
5. _____ _____ _____	☐ Leather ☐ Fabric ☐ Melamine ☐ Particleboard ☐ Wood ☐ Plywood ☐ MDF* ☐ I prefer not to say ☐ Other: _____	_____ _____ ☐ I prefer not to say	☐ Yes ☐ No ☐ I prefer not to say	_____/_____ mm / yyyy ☐ I prefer not to say
6. _____ _____ _____	☐ Leather ☐ Fabric ☐ Melamine ☐ Particleboard ☐ Wood ☐ Plywood ☐ MDF* ☐ I prefer not to say ☐ Other: _____	_____ _____ ☐ I prefer not to say	☐ Yes ☐ No ☐ I prefer not to say	_____/_____ mm / yyyy ☐ I prefer not to say
7. _____ _____ _____	☐ Leather ☐ Fabric ☐ Melamine ☐ Particleboard ☐ Wood ☐ Plywood ☐ MDF* ☐ I prefer not to say ☐ Other: _____	_____ _____ ☐ I prefer not to say	☐ Yes ☐ No ☐ I prefer not to say	_____/_____ mm / yyyy ☐ I prefer not to say
Type of furniture	Material (Check all that apply)	Room	Monitored room	Date installed
8. _____ _____ _____	☐ Leather ☐ Fabric ☐ Melamine ☐ Particleboard ☐ Wood ☐ Plywood ☐ MDF* ☐ I prefer not to say	_____ _____ ☐ I prefer not to say	☐ Yes ☐ No ☐ I prefer not to say	_____/_____ mm / yyyy ☐ I prefer not to say

	☐ Other: _____			
9. _____ _____ _____	☐ Leather ☐ Fabric ☐ Melamine ☐ Particleboard ☐ Wood ☐ Plywood ☐ MDF* ☐ I prefer not to say ☐ Other: _____	_____ _____ ☐ I prefer not to say	☐ Yes ☐ No ☐ I prefer not to say	_____ / _____ mm / yyyy ☐ I prefer not to say
10. _____ _____ _____	☐ Leather ☐ Fabric ☐ Melamine ☐ Particleboard ☐ Wood ☐ Plywood ☐ MDF* ☐ I prefer not to say ☐ Other: _____	_____ _____ ☐ I prefer not to say	☐ Yes ☐ No ☐ I prefer not to say	_____ / _____ mm / yyyy ☐ I prefer not to say

*MDF: Medium-density fibreboard

Q21. Do you keep any paints or solvents in your home?

- ☐ No
- ☐ Yes
- ☐ I prefer not to say

Q22. In the past 3 months, have you or anyone else, including a professional exterminator, used any pesticides (for example, rodent poison or bug sprays, including for spiders) inside your home?

- ☐ No
- ☐ Yes, Please specify for what purpose: _____ and pesticide name: _____
- ☐ I don't know
- ☐ I prefer not to say

Q23. In what year was your attached garage built? _____

- ☐ I prefer not to say
- ☐ I don't know

Q24. Does your garage have an additional door (other than the main garage door) leading to the outside?

- ☐ No
- ☐ Yes
- ☐ I prefer not to say

Q25. Do you have a dedicated exhaust system to vent garage air to the outside?

- ☐ No
- ☐ Yes
- ☐ I prefer not to say

Q26. Do you have any air ducts from a forced air system running through the wall of the garage and your home?

- ☐ No
- ☐ Yes
- ☐ I prefer not to say

Q27. Do you have a dedicated heating system for the garage?

- ☐ No
- ☐ Yes, in use
- ☐ Yes, not in use
- ☐ I prefer not to say

If yes (in use or not), please indicate the primary heating fuel used.

- ☐ Oil
- ☐ Electric
- ☐ Propane
- ☐ Natural gas
- ☐ Other, please specify: _____
- ☐ I prefer not to say

Q28. Do you have a connection to a central vacuum system through the wall between the garage and the house?

- ☐ No
- ☐ Yes
- ☐ I prefer not to say

Q29. Does your garage have any windows?

- ☐ No
- ☐ Yes, how many: _____
- ☐ I prefer not to say

Q30. Are any walls and / or ceiling in your garage insulated? *Check all that apply.*

- ☐ No
- ☐ The interface between the garage and the home
- ☐ All the walls
- ☐ The ceiling
- ☐ Other, please specify: _____
- ☐ I don't know
- ☐ I prefer not to say

Q31. What is the assessed value of your home based on your 2012 Property Tax Assessment?

\$ _____ (See column 1 on your Tax Bill)

☐ I prefer not to say

☐ I don't know

Comments:

9 Appendix B: List of VOCs Analyzed using Summa Canisters

Table 9-1: List of VOCs analyzed using Summa Canisters

ID	VOC	Group	MW (g/mol)
S001	Acetylene	alkyne	26.04
S002	Ethylene	alkene	28.05
S003	Ethane	alkane	30.07
S004	Methanol	alcohol	32.04
S005	Propyne	alkyne	40.06
S006	Acetonitrile	nitrile	41.05
S007	Propene	alkene	42.08
S008	Acetaldehyde	aldehyde	44.05
S009	Ethylene oxide	heterocyclic compound	44.05
S010	Propane	alkane	44.10
S011	Ethanol	alcohol	46.07
S012	Chloromethane	haloalkane	50.49
S013	Acrylonitrile (2-Propennitrile)	nitrile	53.06
S014	1-Butyne	alkyne	54.09
S015	1,3-Butadiene	alkene	54.09
S016	Acrolein (2-Propenal)	aldehyde	56.06
S017	1-Butene/2-Methylpropene	alkene	56.11
S018	c-2-Butene	alkene	56.11
S019	t-2-Butene	alkene	56.11
S020	Acetone	ketone	58.08
S021	Propionaldehyde	aldehyde	58.08
S022	Propylene Oxide	heterocyclic compound	58.08
S023	Butane	alkane	58.12
S024	Isobutane (2-Methylpropane)	alkane	58.12
S025	Isopropyl Alcohol	alcohol	60.10
S026	Propyl alcohol (1-Propanol)	alcohol	60.10
S027	Vinylchloride (Chloroethene)	haloalkene	62.50
S028	Chloroethane	haloalkane	64.51
S029	Cyclopentene	cycloalkene	68.11
S030	Isoprene (2-Methyl-1-3-Butadiene)	alkene	68.12
S031	MVK	ketone	70.09
S032	Cyclopentane	cycloalkane	70.10
S033	1-Pentene	alkene	70.13
S034	c-2-Pentene	alkene	70.13
S035	t-2-Pentene	alkene	70.13
S036	2-Methyl-1-Butene	alkene	70.13
S037	2-Methyl-2-Butene	alkene	70.13

S038	3-Methyl-1-Butene	alkene	70.13
S039	2-Butenal (Crotonaldehyde)	aldehyde	72.11
S040	2-Methyl-Propanal	aldehyde	72.11
S041	Butylaldehyde (Butanal)	aldehyde	72.11
S042	MEK (2-Butanone)	ketone	72.11
S043	2,2-Dimethylpropane	alkane	72.15
S044	2-Methylbutane	alkane	72.15
S045	Pentane	alkane	72.15
S046	Methyl Acetate	ester	74.08
S047	1-Butanol (Butyl alcohol)	alcohol	74.12
S048	2-Butanol	alcohol	74.12
S049	Isobutylalcohol	alcohol	74.12
S050	Carbon Disulfide	sulfide	76.14
S051	Benzene	aromatic	78.11
S052	2-Methylfuran	heterocyclic compound	82.10
S053	3-Methylfuran	heterocyclic compound	82.10
S054	1-Methylcyclopentene	cycloalkene	82.14
S055	Cyclohexene	cycloalkene	82.14
S056	Cyclopentanone	cyclic ketone	84.12
S057	2-Ethyl-1-Butene	alkene	84.16
S058	3-Methyl-1-Pentene	alkene	84.16
S059	4-Methyl-1-Pentene	alkene	84.16
S060	c-2-Hexene	alkene	84.16
S061	c-3-Methyl-2-Pentene	alkene	84.16
S062	c-4-Methyl-2-Pentene	alkene	84.16
S063	Cyclohexane	cycloalkane	84.16
S064	Methylcyclopentane	cycloalkane	84.16
S065	t-2-Hexene	alkene	84.16
S066	t-3-Methyl-2-Pentene	alkene	84.16
S067	t-4-Methyl-2-Pentene	alkene	84.16
S068	1-Hexene/2-Methyl-1-Pentene	alkene	84.16
S069	Dichloromethane	haloalkane	84.93
S070	2-Methylbutanal(Isovaleraldehyde)	aldehyde	86.13
S071	2-Pentanone	ketone	86.13
S072	Pentanal	aldehyde	86.13
S073	2,2-Dimethylbutane	alkane	86.17
S074	2,3-Dimethylbutane	alkane	86.17
S075	2-Methylpentane	alkane	86.18
S076	3-Methylpentane	alkane	86.18
S077	Hexane	alkane	86.18
S078	Freon 22 (Chlorodifluoromethane)	hydrochlorofluorocarbon	86.47
S079	Ethylacetate	ester	88.11
S080	Methyl-t-Butyl Ether (MTBE)	ether	88.15

S081	3-Methyl-1-Butanol	alcohol	88.15
S082	MAC (2-Methyl-2-propenal)	aldehyde	90.55
S083	Toluene	aromatic	92.14
S084	Bromomethane	haloalkane	94.94
S085	c-1,2-Dichloroethene	haloalkene	96.94
S086	t-1,2-Dichloroethene	haloalkene	96.94
S087	1,1-Dichloroethene	haloalkene	96.95
S088	Cyclohexanone	cyclic ketone	98.15
S089	1-Methylcyclohexene	cycloalkene	98.19
S090	1-Heptene	alkene	98.19
S091	c-2-Heptene	alkene	98.19
S092	c-3-Heptene	alkene	98.19
S093	Methylcyclohexane	alicyclic hydrocarbon	98.19
S094	t-2-Heptene	alkene	98.19
S095	t-3-Heptene	alkene	98.19
S096	1,1-Dichloroethane	haloalkane	98.96
S097	1,2-Dichloroethane	haloalkane	98.96
S098	Hexanal	aldehyde	100.16
S099	MIBK	ketone	100.16
S100	2-Hexanone	ketone	100.16
S101	2,2,3-Trimethylbutane	alkane	100.20
S102	2,2-Dimethylpentane	alkane	100.20
S103	2,3-Dimethylpentane	alkane	100.20
S104	2-Methylhexane	alkane	100.20
S105	3-Methylhexane	alkane	100.20
S106	Heptane	alkane	100.20
S107	2,4-Dimethylpentane	alkane	100.20
S108	Freon 134A	hydrochlorofluorocarbon	102.03
S109	Isopropylacetate	ester	102.13
S110	Styrene	aromatic	104.15
S111	Benzaldehyde	aromatic	106.12
S112	Ethylbenzene	aromatic	106.17
S113	m-, p-Xylene	aromatic	106.17
S114	o-Xylene	aromatic	106.17
S115	Ethylbromide	haloalkane	108.97
S116	c-1,3-Dichloropropene	haloalkene	110.97
S117	t-1,3-Dichloropropene	haloalkene	110.97
S118	c-1,2-Dimethylcyclohexane	alicyclic hydrocarbon	112.21
S119	c-1,3-Dimethylcyclohexane	alicyclic hydrocarbon	112.21
S120	c-1,4/t-1,3-Dimethylcyclohexane	alicyclic hydrocarbon	112.21
S121	t-1,2-Dimethylcyclohexane	alicyclic hydrocarbon	112.21
S122	t-1,4-Dimethylcyclohexane	alicyclic hydrocarbon	112.21
S123	t-2-Octene	alkene	112.21

S124	1-Octene	alkene	112.24
S125	Chlorobenzene	haloaromatic	112.56
S126	1,2-Dichloropropane	haloalkane	112.99
S127	2-Heptanone	ketone	114.19
S128	2,2,4-Trimethylpentane	alkane	114.22
S129	2,3,4-Trimethylpentane	alkane	114.22
S130	2,2-Dimethylhexane	alkane	114.23
S131	2,4-Dimethylhexane	alkane	114.23
S132	2,5-Dimethylhexane	alkane	114.23
S133	2-Methylheptane	alkane	114.23
S134	3-Methylheptane	alkane	114.23
S135	4-Methylheptane	alkane	114.23
S136	Octane	alkane	114.23
S137	Butylacetate	ester	116.16
S138	Isobutylacetate	ester	116.16
S139	Indan (2-3-Dihydroindene)	aromatic	118.18
S140	Chloroform	haloalkane	119.38
S141	1,2,3-Trimethylbenzene	aromatic	120.19
S142	1,2,4-Trimethylbenzene	aromatic	120.19
S143	1,3,5-Trimethylbenzene	aromatic	120.19
S144	2-Ethyltoluene	aromatic	120.19
S145	3-Ethyltoluene	aromatic	120.19
S146	4-Ethyltoluene	aromatic	120.19
S147	iso-Propylbenzene	aromatic	120.19
S148	n-Propylbenzene	aromatic	120.19
S149	Freon 12 (Dichlorodifluoromethane)	hydrochlorofluorocarbon	120.91
S150	1-Nonene	alkene	126.24
S151	Benzyl Chloride	aromatic	126.58
S152	1,4-Dichlorobutane	haloalkane	127.01
S153	2,2,5-Trimethylhexane	alkane	128.16
S154	Naphthalene	polycyclic aromatic hydrocarbon	128.17
S155	Nonane	alkane	128.26
S156	Trichloroethene	haloalkene	131.39
S157	1,1,1-Trichloroethane	haloalkene	133.40
S158	1,1,2-Trichloroethane	haloalkene	133.40
S159	1,2,4,5-Tetramethylbenzene	aromatic	134.22
S160	1,2-Diethylbenzene	aromatic	134.22
S161	1,3-Diethylbenzene	aromatic	134.22
S162	1,4-Diethylbenzene	aromatic	134.22
S163	iso-Butylbenzene	aromatic	134.22
S164	n-Butylbenzene	aromatic	134.22
S165	p-Cymene (1-Methyl-4-Isopropylbenzene)	aromatic	134.22
S166	sec-Butylbenzene	aromatic	134.22

S167	tert-Butylbenzene	aromatic	134.22
S168	a-Pinene	monoterpene	136.23
S169	b-Pinene	monoterpene	136.23
S170	Limonene	cyclic terpene	136.23
S171	Camphene	monoterpene	136.24
S172	Freon 11 (Trichlorofluoromethane)	hydrochlorofluorocarbon	137.37
S173	1-Decene	alkene	140.27
S174	Nonanal	aldehyde	142.24
S175	3,6-Dimethyloctane	alkane	142.28
S176	Decane	alkane	142.29
S177	1,2-Dichlorobenzene	haloaromatic	147.01
S178	1,3-Dichlorobenzene	haloaromatic	147.01
S179	1,4-Dichlorobenzene	haloaromatic	147.01
S180	Carbon tetrachloride	haloalkane	153.82
S181	1-Undecene	alkane	154.29
S182	Decanal	aldehyde	156.20
S183	Undecane	alkane	156.31
S184	Hexylbenzene	aromatic	162.27
S185	Bromodichloromethane	haloalkane	163.83
S186	Tetrachloroethene	haloalkene	165.83
S187	1,1,2,2-Tetrachloroethane	haloalkane	167.85
S188	Dodecane	alkane	170.33
S189	Freon 114 (1,2-Dichlorotetrafluoroethane)	hydrochlorofluorocarbon	170.92
S190	Dibromomethane	haloalkane	173.83
S191	1,2,4-Trichlorobenzene	haloaromatic	181.45
S192	Tridecane	alkane	184.36
S193	Freon 113 (1,1,2-Trichlorotrifluoroethane)	hydrochlorofluorocarbon	187.38
S194	1,2-Dibromoethane	haloalkane	187.86
S195	Bromotrichloromethane	haloalkane	198.27
S196	Tetradecane	alkane	198.39
S197	Dibromochloromethane	haloalkane	208.28
S198	Pentadecane	alkane	212.41
S199	Hexadecane	alkane	226.44
S200	Bromoform	haloalkane	252.73
S201	Hexachlorobutadiene	haloalkene	260.76

10 Appendix C: Summary Statistics for Each Microenvironment

Table 10-1: Summary Statistics for the Outdoor Microenvironment

Outdoor												
Variable	Mean	StDev	CoefVar	Minimum	Q1	Median	Q3	Maximum	Range	IQR	Skewness	Kurtosis
S001	0.8386	0.4591	54.74	0.3	0.52	0.6943	0.9671	3.1293	2.8293	0.4471	2	5.87
S002	1.2556	0.776	61.8	0.2511	0.6466	0.9662	1.6036	3.3550	3.1039	0.957	0.97	-0.13
S003	3.939	1.279	32.47	1.571	2.947	3.776	4.623	7.709	6.138	1.675	0.67	0.09
S004	22.21	21.46	96.63	0	6.6	13.05	36.94	93.09	93.09	30.34	1.46	1.71
S005	0.05468	0.03159	57.77	0.016	0.032	0.04	0.068	0.14000	0.124	0.036	1.12	0.09
S006	0.15722	0.09602	61.07	0.052	0.12	0.144	0.18	0.99200	0.94	0.06	6.76	57.04
S007	0.3542	0.1935	54.65	0.076	0.196	0.296	0.468	0.8840	0.808	0.272	0.9	-0.10
S008	8.96	10.68	119.16	2.66	4.39	6.7	9.58	99.50	96.84	5.19	6.51	51.75
S009	0.0473	0.2483	525.41	0	0	0	0	2.1280	2.128	0	6.84	51.96
S010	3.647	1.175	32.21	1.795	2.805	3.324	4.403	6.857	5.062	1.598	1.02	0.11
S011	4.831	4.015	83.11	0.34	2.144	3.884	6.532	27.816	27.476	4.388	2.95	13.36
S012	1.2592	0.0661	5.25	1.084	1.212	1.26	1.296	1.4640	0.38	0.084	0.29	0.55
S013	0	0	*	0	0	0	0	0.000000	0	0	*	*
S014	0.002524	0.002855	113.12	0	0	0	0.004	0.008000	0.008	0.004	0.68	-0.76
S015	0.04831	0.03289	68.07	0.008	0.024	0.036	0.068	0.14000	0.132	0.044	1.08	0.19
S016	4.905	7.63	155.54	0.764	2.056	3.1	4.996	64.344	63.58	2.94	5.71	38.76
S017	0.2856	0.1511	52.93	0.068	0.164	0.228	0.376	0.7600	0.692	0.212	0.94	0.35
S018	0.05891	0.05652	95.94	0.008	0.024	0.036	0.08	0.34000	0.332	0.056	2.56	9.03
S019	0.07297	0.07858	107.69	0.012	0.024	0.044	0.088	0.50800	0.496	0.064	3	12.18
S020	7.467	6.633	88.83	2.408	4.78	6.136	8.192	63.932	61.524	3.412	6.5	52.47
S021	0	0	*	0	0	0	0	0.000000	0	0	*	*
S022	0	0	*	0	0	0	0	0.000000	0	0	*	*

S023	2.968	2.06	69.41	1.056	1.628	2.08	3.888	14.072	13.016	2.26	2.46	8.65
S024	1.49	1.161	77.91	0.504	0.752	0.996	1.872	7.792	7.288	1.12	2.67	9.85
S025	0.2362	0.8979	380.1	0	0	0	0	6.1520	6.152	0	4.54	22.47
S026	0.2571	0.3977	154.68	0	0.06	0.14	0.288	3.2920	3.292	0.228	4.79	32.95
S027	0.004078	0.00125	30.66	0	0.004	0.004	0.004	0.008000	0.008	0	0.46	7.67
S028	0.022837	0.00928	40.64	0.012	0.016	0.02	0.028	0.056000	0.044	0.012	1.65	3.28
S029	0.011535	0.008218	71.25	0	0.004	0.008	0.016	0.040000	0.04	0.012	1.53	2.43
S030	0.03561	0.02469	69.32	0.004	0.016	0.028	0.052	0.10000	0.096	0.036	0.91	-0.08
S031	0.2083	0.4726	226.81	0	0	0	0	2.8640	2.864	0	2.95	10.80
S032	0.08556	0.05161	60.33	0.028	0.048	0.06	0.112	0.25200	0.224	0.064	1.32	0.98
S033	0.0576	0.02835	49.23	0.016	0.036	0.052	0.076	0.14000	0.124	0.04	0.82	0.12
S034	0.03107	0.02612	84.08	0	0.012	0.02	0.044	0.13200	0.132	0.032	1.52	2.14
S035	0.06047	0.05285	87.4	0.008	0.024	0.044	0.084	0.27200	0.264	0.06	1.58	2.40
S036	0.06517	0.04873	74.77	0.012	0.028	0.044	0.096	0.22800	0.216	0.068	1.25	0.98
S037	0.0734	0.06531	88.98	0.008	0.028	0.048	0.108	0.33200	0.324	0.08	1.62	2.70
S038	0.01996	0.01367	68.47	0.004	0.012	0.012	0.028	0.08000	0.076	0.016	1.47	2.86
S039	0.1279	0.6728	526.11	0	0	0	0	6.2200	6.22	0	7.74	67.51
S040	0.382	1.072	280.89	0	0.18	0.236	0.316	10.820	10.82	0.136	9.3	90.58
S041	1.567	1.177	75.14	0	1.044	1.28	1.704	10.356	10.356	0.66	4.53	30.33
S042	1.662	3.936	236.8	0.484	0.796	1.02	1.244	37.940	37.456	0.448	8.19	73.03
S043	0.017089	0.00684	40.03	0.008	0.012	0.016	0.02	0.052000	0.044	0.008	2.08	6.68
S044	0.098	0.1964	200.38	0	0	0	0.168	1.1440	1.144	0.168	2.72	9.19
S045	0.9015	0.5026	55.75	0.348	0.552	0.652	1.212	2.9640	2.616	0.66	1.45	2.13
S046	0.162	0.1222	75.45	0	0.092	0.132	0.224	0.7920	0.792	0.132	1.7	5.77
S047	0.0769	0.1319	171.58	0	0	0	0.148	0.8720	0.872	0.148	2.83	12.35
S048	0.0359	0.2308	643.1	0	0	0	0	2.1880	2.188	0	8.57	77.29
S049	0.00559	0.0473	845.76	0	0	0	0	0.47200	0.472	0	9.65	95.36
S050	0.1357	0.16	117.97	0.06	0.08	0.1	0.144	1.5920	1.532	0.064	7.69	68.54
S051	0.6738	0.2503	37.15	0.292	0.488	0.6	0.792	1.3840	1.092	0.304	1.13	0.27

S052	0.06509	0.06419	98.62	0	0.032	0.044	0.08	0.53200	0.532	0.048	4.44	28.17
S053	0.000544	0.003801	699.09	0	0	0	0	0.036000	0.036	0	8.46	76.66
S054	0.01398	0.01264	90.38	0	0.004	0.012	0.02	0.06400	0.064	0.016	1.66	3.35
S055	0.006058	0.007978	131.68	0	0	0	0.012	0.044000	0.044	0.012	1.49	3.50
S056	0.00885	0.03095	349.56	0	0	0	0	0.19600	0.196	0	4.01	17.12
S057	0	0	*	0	0	0	0	0.000000	0	0	*	*
S058	0.005903	0.004545	77	0	0.004	0.004	0.008	0.016000	0.016	0.004	0.41	-0.76
S059	0.002641	0.004394	166.41	0	0	0	0.004	0.016000	0.016	0.004	1.48	0.96
S060	0.010408	0.007543	72.47	0	0.004	0.008	0.012	0.040000	0.04	0.008	1.34	2.42
S061	0.02012	0.0178	88.46	0	0.008	0.016	0.028	0.07600	0.076	0.02	1.24	1.40
S062	0.007728	0.007113	92.04	0	0.004	0.004	0.012	0.028000	0.028	0.008	1.3	1.21
S063	0.07927	0.045	56.77	0.028	0.048	0.06	0.1	0.23200	0.204	0.052	1.42	1.30
S064	0.1435	0.09001	62.73	0.044	0.084	0.104	0.18	0.41200	0.368	0.096	1.3	0.79
S065	0.0174	0.01293	74.31	0	0.008	0.012	0.024	0.05600	0.056	0.016	1.25	1.13
S066	0.008544	0.008233	96.36	0	0.004	0.008	0.012	0.032000	0.032	0.008	1.07	0.63
S067	0.000971	0.002203	226.88	0	0	0	0	0.008000	0.008	0	2.22	3.90
S068	0.05639	0.04387	77.79	0.012	0.032	0.048	0.068	0.39200	0.38	0.036	4.67	33.16
S069	0.4147	0.1738	41.9	0.268	0.3126	0.34	0.472	1.1680	0.9	0.1594	2.39	6.40
S070	1.3906	0.9583	68.91	0.456	0.74	0.924	1.84	5.6960	5.24	1.1	1.75	3.84
S071	0.685	2.742	400.35	0	0	0.236	0.444	25.672	25.672	0.444	7.97	69.88
S072	0.602	1.144	189.95	0	0	0	0.908	6.612	6.612	0.908	2.53	7.96
S073	0.0708	0.04147	58.57	0.024	0.044	0.052	0.096	0.20400	0.18	0.052	1.38	1.37
S074	0.0816	0.05524	67.7	0.024	0.044	0.056	0.108	0.27200	0.248	0.064	1.36	1.26
S075	0.824	2.175	263.87	0.056	0.244	0.432	0.756	21.408	21.352	0.512	8.61	80.60
S076	0.2632	0.1668	63.36	0.076	0.144	0.184	0.352	0.7560	0.68	0.208	1.23	0.69
S077	0.3595	0.2102	58.47	0.104	0.212	0.272	0.468	1.0560	0.952	0.256	1.28	0.95
S078	0.80037	0.09426	11.78	0.648	0.732	0.772	0.828	1.06400	0.416	0.096	1.04	0.39
S079	0.12444	0.10009	80.43	0	0.052	0.088	0.176	0.44000	0.44	0.124	1.16	0.63
S080	0.000233	0.001664	714.11	0	0	0	0	0.012000	0.012	0	7.07	48.92

S081	0.00505	0.05124	1014.89	0	0	0	0	0.52000	0.52	0	10.15	103.00
S082	0.1446	0.1937	134.02	0	0.076	0.112	0.16	1.8400	1.84	0.084	7.02	58.83
S083	1.016	0.6797	66.9	0.26	0.52	0.74	1.412	2.8680	2.608	0.892	1.05	0.01
S084	0.052745	0.006201	11.76	0.04	0.048	0.052	0.056	0.076000	0.036	0.008	0.7	0.74
S085	0.000777	0.001686	217.04	0	0	0	0	0.008000	0.008	0	1.96	2.96
S086	0.02155	0.03203	148.58	0.004	0.004	0.00812	0.02	0.20000	0.196	0.016	3.21	12.06
S087	0.000544	0.001487	273.51	0	0	0	0	0.008000	0.008	0	2.72	7.14
S088	0.00711	0.01929	271.41	0	0	0	0	0.14800	0.148	0	4.64	28.50
S089	0.004699	0.0048	102.14	0	0.004	0.004	0.008	0.040000	0.04	0.004	4.03	27.95
S090	0.00524	0.01687	321.76	0	0	0	0	0.08000	0.08	0	3.22	9.39
S091	0.000816	0.005667	694.86	0	0	0	0	0.056000	0.056	0	9.29	90.50
S092	0.00035	0.002512	718.59	0	0	0	0	0.020000	0.02	0	7.2	51.55
S093	0.08292	0.0561	67.66	0.028	0.048	0.06	0.116	0.38400	0.356	0.068	2.18	7.24
S094	0.005903	0.004297	72.79	0	0.004	0.004	0.008	0.020000	0.02	0.004	0.84	0.52
S095	0.006447	0.005379	83.44	0	0.004	0.004	0.012	0.020000	0.02	0.008	0.82	-0.06
S096	0.000078	0.000788	1014.89	0	0	0	0	0.008000	0.008	0	10.15	103.00
S097	0.080477	0.005657	7.03	0.068	0.076	0.08	0.084	0.100000	0.032	0.008	0.23	0.53
S098	1.41	1.309	92.85	0	0.9	1.108	1.656	10.256	10.256	0.756	4.4	24.46
S099	0.0707	0.167	236.1	0.012	0.028	0.036	0.052	1.6040	1.592	0.024	8.01	71.55
S100	0.205	1.025	500.84	0	0	0.064	0.092	10.212	10.212	0.092	9.37	91.54
S101	0.01037	0.02547	245.62	0	0.004	0.004	0.008	0.23200	0.232	0.004	7.17	58.64
S102	0.016389	0.009948	60.7	0.004	0.008	0.012	0.02	0.044000	0.04	0.012	1.15	0.57
S103	0.09271	0.05719	61.69	0.028	0.048	0.068	0.128	0.23600	0.208	0.08	1.03	-0.07
S104	0.3823	0.2547	66.61	0.104	0.204	0.26	0.512	1.1360	1.032	0.308	1.32	0.95
S105	0.2509	0.1659	66.14	0	0.124	0.18	0.352	0.7120	0.712	0.228	0.94	-0.14
S106	0.2143	0.1302	60.77	0.06	0.116	0.152	0.312	0.5680	0.508	0.196	1.04	-0.06
S107	0.0473	0.02808	59.37	0.012	0.028	0.036	0.06	0.12000	0.108	0.032	1.16	0.37
S108	0.5373	0.2462	45.83	0.32	0.388	0.44	0.608	1.8800	1.56	0.22	2.82	10.90
S109	0.00035	0.003547	1014.89	0	0	0	0	0.036000	0.036	0	10.15	103.00

S110	0.01647	0.01537	93.36	0	0.004	0.012	0.024	0.08000	0.08	0.02	1.5	2.37
S111	0.2886	0.2966	102.79	0.112	0.192	0.224	0.324	3.0440	2.932	0.132	8.08	74.51
S112	0.14152	0.08332	58.87	0.032	0.072	0.116	0.204	0.38400	0.352	0.132	0.82	-0.14
S113	0.3948	0.2786	70.57	0.056	0.164	0.312	0.584	1.2000	1.144	0.42	0.88	-0.12
S114	0.15092	0.09763	64.69	0.028	0.068	0.124	0.216	0.40400	0.376	0.148	0.76	-0.31
S115	0.002485	0.002512	101.08	0	0	0.004	0.004	0.016000	0.016	0.004	1.46	6.62
S116	0	0	*	0	0	0	0	0.000000	0	0	*	*
S117	0.000039	0.000394	1014.89	0	0	0	0	0.004000	0.004	0	10.15	103.00
S118	0.008738	0.003829	43.82	0	0.008	0.008	0.012	0.024000	0.024	0.004	0.65	1.66
S119	0.02427	0.0194	79.91	0.008	0.012	0.016	0.032	0.12800	0.12	0.02	2.22	7.29
S120	0.010292	0.007732	75.13	0.004	0.004	0.008	0.016	0.044000	0.04	0.012	1.54	2.72
S121	0.01484	0.01154	77.8	0	0.008	0.008	0.02	0.08000	0.08	0.012	2.32	8.88
S122	0.009049	0.006813	75.29	0.004	0.004	0.008	0.012	0.044000	0.04	0.008	1.92	5.73
S123	0.00217	0.01255	576.92	0	0	0	0	0.12400	0.124	0	9.22	89.45
S124	0.04291	0.03815	88.9	0.008	0.02	0.032	0.052	0.32000	0.312	0.032	4.29	27.30
S125	0.008195	0.002401	29.3	0.004	0.008	0.008	0.008	0.016000	0.012	0	0.26	0.70
S126	0.024547	0.003962	16.14	0.016	0.02	0.024	0.028	0.036000	0.02	0.008	0.27	-0.06
S127	0.02823	0.06281	222.49	0	0	0.008	0.036	0.56800	0.568	0.036	6.64	54.53
S128	0.14448	0.08881	61.47	0	0.08	0.116	0.192	0.36400	0.364	0.112	0.92	-0.01
S129	0.04839	0.03012	62.23	0.012	0.024	0.036	0.068	0.13200	0.12	0.044	1.05	0.37
S130	0.000427	0.004335	1014.89	0	0	0	0	0.044000	0.044	0	10.15	103.00
S131	0.03095	0.02177	70.33	0	0.016	0.024	0.044	0.08800	0.088	0.028	0.96	0.21
S132	0.03029	0.01904	62.85	0	0.016	0.024	0.044	0.08800	0.088	0.028	1	0.43
S133	0.2068	0.1348	65.18	0.052	0.104	0.148	0.288	0.5680	0.516	0.184	1.01	-0.13
S134	0.05293	0.03699	69.88	0.012	0.024	0.036	0.076	0.16400	0.152	0.052	1.27	0.95
S135	0.02163	0.01458	67.39	0	0.012	0.016	0.032	0.06400	0.064	0.02	1.12	0.59
S136	0.06944	0.03861	55.61	0.02	0.04	0.052	0.096	0.21600	0.196	0.056	1.14	1.04
S137	0.03953	0.06661	168.48	0	0	0	0.048	0.38400	0.384	0.048	2.66	8.53
S138	0	0	*	0	0	0	0	0.000000	0	0	*	*

S139	0.01724	0.01119	64.89	0	0.008	0.016	0.024	0.05200	0.052	0.016	0.79	0.20
S140	0.09061	0.01843	20.34	0.068	0.076	0.084	0.096	0.15600	0.088	0.02	1.46	1.71
S141	0.03398	0.02448	72.03	0.004	0.012	0.028	0.052	0.11600	0.112	0.04	0.85	0.37
S142	0.1464	0.1115	76.18	0.004	0.052	0.128	0.228	0.5080	0.504	0.176	0.88	0.33
S143	0.0365	0.02958	81.03	0	0.012	0.032	0.056	0.13200	0.132	0.044	0.98	0.56
S144	0.03926	0.02577	65.64	0.004	0.016	0.036	0.06	0.12000	0.116	0.044	0.83	0.12
S145	0.09123	0.06457	70.78	0.004	0.036	0.08	0.144	0.29600	0.292	0.108	0.88	0.26
S146	0.05196	0.03723	71.66	0.004	0.02	0.044	0.08	0.16800	0.164	0.06	0.89	0.20
S147	0.0127	0.007094	55.86	0.004	0.008	0.012	0.016	0.032000	0.028	0.008	0.9	0.24
S148	0.03818	0.02124	55.63	0.008	0.02	0.036	0.056	0.09600	0.088	0.036	0.58	-0.41
S149	2.5594	0.1148	4.49	2.272	2.48	2.552	2.636	2.8400	0.568	0.156	0.11	-0.06
S150	0.02893	0.01792	61.95	0	0.016	0.028	0.04	0.10000	0.1	0.024	1.12	2.58
S151	0.002524	0.005343	211.66	0	0	0	0.004	0.044000	0.044	0.004	5.09	35.75
S152	0.000699	0.004633	662.82	0	0	0	0	0.040000	0.04	0	7.41	57.45
S153	0.014525	0.009471	65.21	0.004	0.008	0.012	0.02	0.040000	0.036	0.012	1.09	0.37
S154	0.1077	0.1047	97.27	0	0.04	0.08	0.144	0.6880	0.688	0.104	2.65	10.74
S155	0.05767	0.0396	68.67	0.012	0.032	0.044	0.08	0.22800	0.216	0.048	1.63	3.21
S156	0.03787	0.03149	83.17	0.012	0.016	0.024	0.048	0.20000	0.188	0.032	2.48	8.19
S157	0.030451	0.004452	14.62	0.024	0.028	0.032	0.032	0.056000	0.032	0.004	1.95	9.67
S158	0.002525	0.004	158.42	0	0	0	0.00406	0.016000	0.016	0.00406	1.4	1.13
S160	0.002874	0.002052	71.39	0	0	0.004	0.004	0.008000	0.008	0.004	-0.3	-0.53
S161	0.008388	0.005726	68.26	0	0.004	0.008	0.012	0.028000	0.028	0.008	0.81	0.50
S162	0.02715	0.01806	66.53	0	0.012	0.024	0.04	0.08000	0.08	0.028	0.64	0.03
S163	0.003223	0.002313	71.77	0	0	0.004	0.004	0.008000	0.008	0.004	0.03	-0.24
S164	0.009437	0.005897	62.49	0	0.004	0.008	0.012	0.028000	0.028	0.008	0.59	0.09
S165	0.013554	0.008255	60.9	0	0.008	0.012	0.02	0.064000	0.064	0.012	2.31	12.48
S166	0.004233	0.002676	63.22	0	0.004	0.004	0.008	0.008000	0.008	0.004	-0.07	-0.73
S167	0.000777	0.001776	228.71	0	0	0	0	0.008000	0.008	0	2.23	4.43
S168	0.05433	0.06617	121.79	0	0.008	0.024	0.084	0.39200	0.392	0.076	2.16	6.73

S169	0.0181	0.03449	190.59	0	0	0	0.02	0.18800	0.188	0.02	2.65	7.96
S170	0.04179	0.07508	179.67	0	0.008	0.016	0.048	0.58800	0.588	0.04	4.72	29.24
S171	0.04637	0.02577	55.56	0	0.028	0.048	0.06	0.16000	0.16	0.032	0.94	2.98
S172	1.5651	0.0802	5.13	1.316	1.516	1.572	1.608	1.7480	0.432	0.092	-0.46	0.57
S173	0.009593	0.009327	97.23	0	0.004	0.008	0.012	0.048000	0.048	0.008	1.54	3.03
S175	0.005282	0.004418	83.65	0	0.004	0.004	0.008	0.024000	0.024	0.004	1.29	2.63
S176	0.07243	0.05159	71.23	0.012	0.032	0.056	0.108	0.30400	0.292	0.076	1.46	3.29
S177	0.008428	0.005007	59.41	0.004	0.004	0.008	0.012	0.024000	0.02	0.008	1.23	1.02
S178	0.008622	0.005921	68.67	0.004	0.004	0.008	0.012	0.032000	0.028	0.008	1.69	2.88
S179	0.04921	0.05497	111.71	0.008	0.02	0.032	0.056	0.33200	0.324	0.036	3.2	12.04
S180	0.46454	0.07523	16.19	0.168	0.42	0.48	0.524	0.58000	0.412	0.104	-1.27	2.67
S181	0.01262	0.02081	164.84	0	0.004	0.008	0.016	0.17200	0.172	0.012	5.51	37.51
S183	0.08024	0.07075	88.18	0.008	0.032	0.064	0.104	0.42000	0.412	0.072	2.26	7.03
S184	0.009088	0.00972	106.96	0	0	0.008	0.012	0.052000	0.052	0.012	2.11	6.37
S185	0.001282	0.003417	266.62	0	0	0	0	0.016000	0.016	0	2.7	6.80
S186	0.1167	0.1392	119.26	0.032	0.048	0.064	0.124	1.1040	1.072	0.076	4.37	25.75
S187	0.001942	0.003112	160.25	0	0	0	0.004	0.016000	0.016	0.004	1.96	4.57
S188	0.05464	0.06697	122.56	0	0.012	0.036	0.076	0.45200	0.452	0.064	2.95	13.03
S189	0.11594	0.00746	6.43	0.1	0.112	0.116	0.12	0.14800	0.048	0.008	0.93	2.74
S190	0.034102	0.004372	12.82	0.024	0.032	0.036	0.036	0.056000	0.032	0.004	1.36	5.92
S191	0.02684	0.0207	77.13	0.008	0.012	0.02	0.036	0.10800	0.1	0.024	1.76	3.26
S193	0.57787	0.03241	5.61	0.476	0.56	0.576	0.596	0.65600	0.18	0.036	-0.17	1.00
S194	0.000854	0.001828	213.95	0	0	0	0	0.008000	0.008	0	2.03	3.45
S195	0	0	*	0	0	0	0	0.000000	0	0	*	*
S197	0.004467	0.001798	40.24	0	0.004	0.004	0.004	0.016000	0.016	0	3.81	19.38
S200	0.020857	0.006595	31.62	0.008	0.016	0.02	0.024	0.040000	0.032	0.008	0.84	0.71
S201	0.005515	0.00275	49.87	0.004	0.004	0.004	0.008	0.016000	0.012	0.004	1.74	2.19

Table 10-2: Summary Statistics for the Indoor Microenvironment

Indoor												
Variable	Mean	StDev	CoefVar	Minimum	Q1	Median	Q3	Maximum	Range	IQR	Skewness	Kurtosis
S001	1.672	1.62	96.87	0.405	0.849	1.259	1.788	9.581	9.175	0.94	3.39	12.71
S002	3.331	2.457	73.76	0.816	1.799	2.426	3.76	15.058	14.241	1.962	2.23	6.00
S003	20.29	27.1	133.56	4.13	7.96	12.13	17.75	132.25	128.11	9.79	3.16	9.39
S004	308.2	459	148.94	43.1	115.5	170.1	267.5	3736.3	3693.2	152	5	32.34
S005	0.1734	0.2447	141.12	0.036	0.068	0.09	0.167	1.5640	1.528	0.099	3.86	16.66
S006	2.212	7.088	320.43	0	0	0	1.673	45.012	45.012	1.673	5.02	26.97
S007	1.1681	0.9937	85.08	0.288	0.565	0.82	1.4338	5.7680	5.48	0.8688	2.33	6.05
S008	43.1	66.94	155.31	4.85	18.78	25.96	44.42	596.56	591.71	25.64	6.37	48.91
S009	0	0	*	0	0	0	0	0.000000	0	0	*	*
S010	25.58	39.66	155.05	3.62	7.48	9.94	26.5	222.43	218.81	19.03	3.28	11.31
S011	945.5	779.2	82.41	39.8	378.1	622.9	1251.5	3242.5	3202.7	873.4	1.14	0.37
S012	1.3785	0.1537	11.15	1.164	1.28	1.346	1.448	2.0120	0.848	0.168	1.44	2.96
S013	0	0	*	0	0	0	0	0.000000	0	0	*	*
S014	0.006087	0.008172	134.26	0	0	0.004	0.008	0.052000	0.052	0.008	2.98	11.75
S015	0.1879	0.2034	108.22	0.04	0.076	0.114	0.216	1.0120	0.972	0.14	2.58	6.95
S016	12.53	12.86	102.63	1.46	6.41	9.59	14.81	100.80	99.34	8.41	4.68	27.38
S017	2.326	3.035	130.51	0.424	0.857	1.404	2.503	18.724	18.3	1.646	3.75	15.48
S018	1.534	2.937	191.48	0.052	0.221	0.478	1.279	16.880	16.828	1.058	3.47	12.72
S019	2.239	4.452	198.89	0.068	0.296	0.676	1.751	25.352	25.284	1.455	3.57	13.24
S020	63.82	66.27	103.84	10.52	31.46	42.7	70.16	496.42	485.9	38.7	4.06	21.17
S021	0	0	*	0	0	0	0	0.000000	0	0	*	*
S022	0	0	*	0	0	0	0	0.000000	0	0	*	*
S023	53.4	109.5	205.18	2.8	8.8	15.6	40.4	591.2	588.4	31.6	3.55	12.90
S024	53.1	103.2	194.43	1.7	6.5	15.6	48.2	665.5	663.8	41.7	3.64	15.02
S025	72.1	167.6	232.45	0	0	4	46.5	831.7	831.7	46.5	3.03	8.96
S026	1.259	1.527	121.23	0	0.637	0.986	1.442	12.772	12.772	0.805	5.28	35.25
S027	0.02172	0.04481	206.31	0.004	0.004	0.008	0.016	0.27600	0.272	0.012	4.11	17.39

S028	0.03482	0.01624	46.65	0.016	0.024	0.032	0.04	0.14000	0.124	0.016	3.43	18.27
S029	0.527	1.216	230.64	0.016	0.065	0.138	0.544	9.112	9.096	0.479	5.1	29.80
S030	3.341	1.912	57.23	0.452	1.951	2.916	4.101	10.900	10.448	2.15	1.27	2.13
S031	0.294	1.544	525.84	0	0	0	0	13.256	13.256	0	6.81	52.41
S032	2.468	4.306	174.49	0.148	0.386	1.156	2.308	26.320	26.172	1.922	3.78	15.36
S033	1.021	2.051	200.84	0.088	0.2	0.338	0.903	14.216	14.128	0.703	4.46	22.47
S034	1.829	4.228	231.17	0.028	0.182	0.41	1.794	28.952	28.924	1.612	4.62	23.57
S035	3.89	8.848	227.48	0.056	0.371	0.92	3.857	59.052	58.996	3.486	4.45	21.65
S036	2.333	5.283	226.44	0	0.306	0.522	2.482	36.068	36.068	2.176	4.55	22.83
S037	5.26	12.35	234.88	0.14	0.54	1.1	5.35	83.12	82.99	4.81	4.54	22.55
S038	0.369	0.7482	202.75	0.024	0.064	0.11	0.344	4.8040	4.78	0.28	4.25	19.72
S039	0.0579	0.2951	509.55	0	0	0	0	1.8200	1.82	0	5.25	27.34
S040	0.8593	0.8198	95.4	0	0.453	0.792	1.089	6.3958	6.3958	0.636	3.61	21.19
S041	3.265	2.123	65	0	1.908	2.546	4.152	12.348	12.348	2.244	1.95	4.65
S042	9.18	18.56	202.16	1.02	2.39	3.96	6.2	121.46	120.44	3.82	4.56	22.35
S043	0.2784	0.8512	305.74	0.016	0.04	0.064	0.153	6.9920	6.976	0.113	6	41.58
S044	1.38	2.095	151.8	0	0	0.244	1.965	10.672	10.672	1.965	2.21	5.55
S045	18.33	39.56	215.83	0	2.86	5.73	16.67	223.50	223.5	13.81	3.98	15.69
S046	1.61	1.582	98.25	0	0.803	1.393	1.939	13.440	13.44	1.136	4.6	31.56
S047	1.071	2.017	188.35	0	0	0	1.351	14.166	14.166	1.351	3.76	18.91
S048	0.094	0.2294	243.92	0	0	0.056	0.116	2.1748	2.1748	0.116	7.8	69.81
S049	0.621	2.664	429.15	0	0	0	0.328	23.316	23.316	0.328	7.14	56.33
S050	0.3779	0.3301	87.35	0	0.196	0.264	0.429	2.2532	2.2532	0.233	3.08	12.13
S051	4.05	6.322	156.08	0.712	1.277	2.241	3.718	32.896	32.184	2.441	3.62	12.82
S052	0.904	1.59	175.87	0	0.23	0.344	1.075	9.580	9.58	0.845	4.45	21.36
S053	0.00128	0.009443	737.75	0	0	0	0	0.084000	0.084	0	7.88	64.59
S054	1.042	2.752	264.12	0.016	0.092	0.228	1.1	20.812	20.796	1.008	5.5	33.29
S055	0.1121	0.2099	187.34	0	0.032	0.0461	0.119	1.4560	1.456	0.087	4.97	26.85
S056	0.00956	0.04591	480.27	0	0	0	0	0.32400	0.324	0	5.29	29.21

S057	0.1388	0.5891	424.41	0	0	0	0	4.3520	4.352	0	5.6	33.49
S058	0.168	0.457	272.04	0	0.024	0.04	0.1447	3.3920	3.392	0.1207	5.56	33.07
S059	0.1231	0.3347	271.82	0	0	0.032	0.114	2.4840	2.484	0.114	5.41	32.00
S060	0.488	1.349	276.5	0.016	0.046	0.102	0.436	9.988	9.972	0.39	5.55	32.94
S061	1.099	2.692	244.84	0	0.121	0.278	1.135	18.936	18.936	1.014	5.12	28.37
S062	0.479	1.339	279.87	0	0.044	0.096	0.423	10.080	10.08	0.379	5.55	33.53
S063	1.236	2.097	169.58	0.12	0.342	0.666	1.253	15.388	15.268	0.911	4.69	25.45
S064	3.098	6.335	204.49	0.188	0.511	1.004	3.023	44.040	43.852	2.512	4.54	23.12
S065	0.967	2.588	267.8	0	0.097	0.214	0.896	18.952	18.952	0.799	5.45	31.89
S066	0.422	1.104	261.61	0	0.044	0.09	0.38	7.716	7.716	0.336	5.22	29.09
S067	0.087	0.2777	319.3	0	0.008	0.016	0.0718	2.3720	2.372	0.0638	6.65	49.60
S068	1.025	2.641	257.63	0.092	0.176	0.29	0.906	20.128	20.036	0.73	5.67	34.68
S069	5.55	11.35	204.52	0.3	0.52	0.99	4.28	72.07	71.76	3.75	3.78	16.67
S070	34.12	74.76	219.11	1.92	6.08	11.37	30.09	429.11	427.2	24.01	4.1	16.86
S071	0.625	2.702	432.16	0	0	0	0	25.402	25.402	0	8.08	73.04
S072	0.478	2.738	573.4	0	0	0	0	19.936	19.936	0	6.6	43.88
S073	1.263	2.962	234.45	0.084	0.201	0.424	0.976	20.540	20.456	0.775	4.63	23.38
S074	2.181	5.9	270.51	0.084	0.277	0.622	1.638	39.968	39.884	1.361	4.93	25.61
S075	2.484	3.521	141.75	0.076	0.938	1.676	2.909	23.155	23.079	1.971	4.58	22.84
S076	5.38	12.17	226.37	0.26	0.88	1.79	4.85	84.10	83.83	3.98	4.71	23.97
S077	6.08	12.14	199.61	0.58	1.15	2.54	6.12	83.86	83.28	4.97	4.5	22.36
S078	7.53	34.34	455.9	0.69	0.78	0.93	1.94	274.84	274.16	1.16	6.56	45.11
S079	10.42	17.19	164.97	0	2.87	6.56	10.11	118.58	118.58	7.24	4.56	23.31
S080	0.00644	0.03301	512.64	0	0	0	0	0.22000	0.22	0	5.3	28.00
S081	0.1135	0.6678	588.23	0	0	0	0	4.6160	4.616	0	6.03	36.19
S082	0.6135	0.4028	65.65	0.148	0.358	0.53	0.772	3.3768	3.2288	0.414	3.6	21.89
S083	27.73	57.96	209.01	2.04	6.15	11.88	25.49	359.45	357.42	19.34	4.85	24.13
S084	0.05605	0.01216	21.7	0.04	0.048	0.05395	0.06	0.12000	0.08	0.012	2.86	11.33
S085	0.001707	0.003541	207.47	0	0	0	0.004	0.020000	0.02	0.004	2.92	9.93

S086	1.356	6.735	496.75	0.004	0.008	0.012	0.02	42.504	42.5	0.012	5.39	28.44
S087	0.00708	0.009845	139.05	0	0	0.004	0.008	0.052000	0.052	0.008	2.66	8.55
S088	0.1139	0.2932	257.39	0	0	0	0.106	2.0520	2.052	0.106	4.56	24.38
S089	0.0993	0.1517	152.75	0.008	0.02	0.036	0.107	0.8120	0.804	0.087	2.81	8.62
S090	0.00752	0.03454	459.27	0	0	0	0	0.23600	0.236	0	4.9	25.05
S091	0.01008	0.03147	312.14	0	0	0	0	0.24800	0.248	0	5.12	33.59
S092	0.00228	0.0228	1000	0	0	0	0	0.22800	0.228	0	10	100.00
S093	1.859	3.319	178.54	0.116	0.413	0.696	1.869	24.272	24.156	1.456	4.18	22.06
S094	0.1813	0.3262	179.96	0.008	0.033	0.0641	0.174	2.0560	2.048	0.141	4.04	18.60
S095	0.2092	0.4149	198.31	0	0.036	0.066	0.182	2.8080	2.808	0.146	4.38	22.03
S096	0.0036	0.0223	619.45	0	0	0	0	0.21200	0.212	0	8.56	79.01
S097	0.534	1.027	192.53	0.076	0.12	0.176	0.507	7.400	7.324	0.387	4.59	24.95
S098	5.259	5.81	110.47	0	1.72	3.644	6.407	37.648	37.648	4.687	2.65	9.88
S099	0.4588	0.3653	79.62	0.084	0.213	0.336	0.604	2.0000	1.916	0.391	1.86	4.28
S100	0.1506	0.5801	385.3	0	0	0	0.112	5.4672	5.4672	0.112	8.06	72.88
S101	0.1052	0.2219	210.9	0	0.032	0.052	0.088	1.6160	1.616	0.056	4.99	27.17
S102	0.2318	0.4404	190	0.028	0.057	0.112	0.224	3.2480	3.22	0.167	4.82	26.59
S103	3.78	20.07	530.47	0.14	0.33	0.63	1.25	196.69	196.55	0.92	9.2	88.56
S104	9.53	22.73	238.39	0.43	1.26	2.94	8.57	158.98	158.55	7.31	4.76	24.59
S105	9.43	56.26	596.7	0.41	0.97	1.83	3.77	562.32	561.91	2.8	9.78	97.00
S106	6.08	23.44	385.25	0.43	1.04	1.81	4.01	229.79	229.36	2.97	9.01	86.07
S107	1.241	3.793	305.63	0.068	0.157	0.32	0.735	27.076	27.008	0.578	5.5	31.51
S108	11.41	50.96	446.5	0.34	0.71	1.01	1.81	414.98	414.64	1.11	6.59	46.31
S109	0.0958	0.3538	369.25	0	0	0	0	2.2360	2.236	0	4.27	18.99
S110	0.2985	0.2364	79.2	0.024	0.136	0.24	0.36	1.3160	1.292	0.224	2.01	5.05
S111	1.3682	0.9331	68.2	0	0.732	1.146	1.829	5.1643	5.1643	1.097	1.33	2.45
S112	8.13	33.19	408.18	0.31	0.81	1.47	3.52	215.45	215.14	2.71	5.62	30.54
S113	26.7	107	400.84	1	2.5	4.9	12.1	720.6	719.7	9.5	5.65	31.26
S114	9.44	38.11	403.59	0.4	0.9	1.75	4.19	264.15	263.75	3.3	5.71	32.18

S115	0.00435	0.003157	72.58	0	0.004	0.004	0.004	0.028000	0.028	0	4.36	31.70
S116	0.00008	0.0008	1000	0	0	0	0	0.008000	0.008	0	10	100.00
S117	0.00032	0.002178	680.72	0	0	0	0	0.020000	0.02	0	8.1	70.15
S118	0.0765	0.1476	193.11	0.008	0.02	0.032	0.08	0.8800	0.872	0.06	4.54	21.48
S119	0.4227	0.9175	217.08	0.028	0.094	0.158	0.467	5.7467	5.7187	0.373	5.03	25.77
S120	0.1498	0.2657	177.34	0.012	0.036	0.064	0.171	1.5800	1.568	0.135	4.44	21.18
S121	0.2816	0.7095	251.96	0.024	0.068	0.1023	0.246	4.4400	4.416	0.178	5.28	27.71
S122	0.1489	0.3104	208.48	0.012	0.036	0.06	0.169	1.9733	1.9613	0.133	5	25.66
S123	0.0528	0.1136	215.42	0	0	0.016	0.048	0.7120	0.712	0.048	3.94	18.08
S124	0.0946	0.1346	142.33	0	0.048	0.074	0.112	1.3160	1.316	0.064	7.74	69.83
S125	0.010042	0.007869	78.37	0	0.004	0.008	0.016	0.032000	0.032	0.012	0.48	-0.31
S126	0.03553	0.01445	40.68	0.02	0.028	0.032	0.039	0.10000	0.08	0.011	2.59	7.76
S127	0.1099	0.1491	135.7	0	0	0.068	0.147	0.8720	0.872	0.147	2.44	7.74
S128	3.03	10.08	332.45	0	0.37	0.71	1.65	66.36	66.36	1.28	5.42	29.49
S129	1.097	3.515	320.34	0.076	0.156	0.265	0.581	21.748	21.672	0.425	5.37	28.27
S130	0.00068	0.0068	1000	0	0	0	0	0.068000	0.068	0	10	100.00
S131	0.771	2.007	260.22	0.06	0.128	0.202	0.527	11.500	11.44	0.399	4.57	20.50
S132	0.654	1.686	257.89	0.052	0.112	0.182	0.455	10.072	10.02	0.343	4.61	20.82
S133	8.89	55.16	620.26	0.34	0.8	1.52	3.29	551.38	551.04	2.49	9.8	97.29
S134	0.872	1.536	176.15	0.092	0.229	0.34	1.015	9.200	9.108	0.786	4.41	21.00
S135	0.3447	0.563	163.31	0.052	0.1	0.152	0.412	3.4120	3.36	0.312	4.43	21.23
S136	1.235	2.576	208.55	0.176	0.357	0.53	1.186	16.573	16.397	0.829	5.13	26.61
S137	3.263	8.586	263.1	0	0.286	0.978	2.34	57.472	57.472	2.054	5.09	28.31
S138	0.4309	0.7529	174.73	0	0	0	0.65	4.0979	4.0979	0.65	2.8	9.24
S139	0.4767	0.9429	197.82	0.06	0.117	0.186	0.487	5.9667	5.9067	0.37	4.8	24.14
S140	1.0034	0.7091	70.67	0.088	0.504	0.842	1.181	3.4520	3.364	0.677	1.56	2.24
S141	1.856	5.654	304.63	0	0.337	0.61	1.085	36.520	36.52	0.748	5.43	28.98
S142	5.81	15.38	264.78	0.62	1.12	2.27	4.73	97.63	97.02	3.62	5.37	28.57
S143	1.588	4.45	280.27	0.136	0.285	0.572	1.195	28.547	28.411	0.91	5.44	29.20

S144	1.302	3.591	275.74	0.136	0.249	0.544	0.989	23.193	23.057	0.74	5.43	29.10
S145	3.064	7.934	258.96	0.34	0.583	1.278	2.741	51.413	51.073	2.158	5.37	28.68
S146	1.599	4.025	251.69	0.176	0.345	0.73	1.417	26.387	26.211	1.072	5.37	28.73
S147	0.402	1.308	325.07	0.032	0.072	0.128	0.255	8.667	8.635	0.183	5.6	30.75
S148	1.183	3.392	286.61	0.124	0.221	0.438	0.891	22.440	22.316	0.67	5.47	29.65
S149	2.9564	0.7639	25.84	2.192	2.513	2.66	3.023	6.5440	4.352	0.51	2.2	5.29
S150	0.1382	0.9049	654.96	0	0	0	0.079	9.0400	9.04	0.079	9.81	97.42
S151	0.00344	0.008452	245.71	0	0	0	0	0.040000	0.04	0	2.78	7.40
S152	0.00144	0.008091	561.86	0	0	0	0	0.064000	0.064	0	6.44	43.90
S153	0.364	1.263	347.26	0.016	0.041	0.078	0.163	8.444	8.428	0.122	5.52	30.10
S154	2.842	8.169	287.42	0	0.269	0.583	1.417	61.628	61.628	1.148	5.52	33.56
S155	3.4	10.05	295.68	0.12	0.44	1.02	1.79	66.33	66.2	1.35	5.28	28.19
S156	0.155	0.3949	254.82	0	0.04	0.064	0.103	2.5000	2.5	0.063	5.36	28.47
S157	1.572	7.428	472.65	0.024	0.036	0.21	0.419	47.304	47.28	0.383	5.66	30.96
S158	0.00032	0.0032	1000	0	0	0	0	0.032000	0.032	0	10	100.00
S160	0.1667	0.5133	307.91	0.008	0.02	0.052	0.106	3.1400	3.132	0.086	5.35	28.06
S161	0.35	1.099	314.03	0.028	0.052	0.1	0.212	6.904	6.876	0.16	5.43	28.85
S162	1.353	4.505	332.86	0	0.168	0.352	0.757	27.412	27.412	0.589	5.43	28.74
S163	0.1645	0.574	349.03	0.008	0.0201	0.044	0.084	3.5733	3.5653	0.0639	5.5	29.47
S164	0.586	2.136	364.85	0.024	0.056	0.126	0.252	12.880	12.856	0.196	5.43	28.64
S165	1.626	1.965	120.86	0.092	0.583	0.91	1.635	9.968	9.876	1.052	2.47	5.94
S166	0.325	1.305	401.73	0.012	0.024	0.056	0.119	8.047	8.035	0.095	5.54	29.81
S167	0.0367	0.1237	337.17	0	0	0.004	0.012	0.7280	0.728	0.012	4.59	21.22
S168	13.85	26.05	188.05	0	2.86	5.19	10.72	140.48	140.48	7.86	3.28	10.93
S169	1.329	2.759	207.54	0	0.016	0.364	1.543	22.532	22.532	1.527	5.23	35.92
S170	26.27	46.84	178.3	0	1.78	12.49	30.06	322.92	322.92	28.28	3.87	18.75
S171	1.574	2.6	165.21	0.104	0.448	0.742	1.189	15.708	15.604	0.741	3.5	13.14
S172	2.227	0.9917	44.53	1.32	1.653	1.914	2.437	7.1840	5.864	0.784	2.81	9.21
S173	0.006	0.02153	358.76	0	0	0	0	0.16800	0.168	0	5.47	35.19

S175	0.2958	0.9882	334.1	0	0.029	0.074	0.171	6.0880	6.088	0.142	5.44	28.81
S176	10.35	35.87	346.56	0.19	1.1	2.05	4.85	222.16	221.98	3.75	5.38	28.36
S177	0.0274	0.06285	229.36	0	0.008	0.012	0.024	0.40800	0.408	0.016	5.34	28.32
S178	0.01089	0.01053	96.71	0	0.004	0.008	0.012	0.05200	0.052	0.008	2.36	5.53
S179	3.14	10.91	347.72	0.04	0.06	0.09	0.23	77.00	76.96	0.17	4.79	25.83
S180	0.48345	0.07574	15.67	0.324	0.433	0.48	0.528	0.87200	0.548	0.095	1.34	5.97
S181	0.0853	0.4539	531.96	0	0	0	0.016	4.0240	4.024	0.016	7.61	61.76
S183	10.81	35.66	329.99	0.14	1.04	2.05	5.82	215.75	215.61	4.78	5.27	27.41
S184	0.04364	0.05376	123.19	0	0.016	0.028	0.056	0.33600	0.336	0.04	3.08	12.26
S185	0.0831	0.1299	156.31	0	0	0	0.14	0.5640	0.564	0.14	2.11	4.58
S186	3.237	9.677	298.99	0.06	0.166	0.514	2.304	66.916	66.856	2.138	5.1	27.44
S187	0.00392	0.01247	318.08	0	0	0	0	0.10000	0.1	0	5.41	36.66
S188	2.42	4.707	194.49	0	0.298	0.946	1.987	21.452	21.452	1.689	3.13	9.02
S189	0.1176	0.01286	10.93	0.1	0.112	0.116	0.12	0.17600	0.076	0.008	2.54	8.64
S190	0.034334	0.00545	15.87	0.028	0.032	0.032	0.036	0.076000	0.048	0.004	4.78	34.31
S191	0.04758	0.04128	86.76	0	0.028	0.036	0.052	0.27600	0.276	0.024	3.25	13.07
S193	0.6126	0.1959	31.99	0.484	0.557	0.576	0.6	1.7800	1.296	0.043	5.37	28.50
S194	0.00108	0.002334	216.12	0	0	0	0	0.016000	0.016	0	3.31	16.24
S195	0	0	*	0	0	0	0	0.000000	0	0	*	*
S197	0.013888	0.009746	70.18	0.004	0.008	0.012	0.016	0.048000	0.044	0.008	1.83	3.28
S200	0.021823	0.008591	39.37	0.012	0.016	0.02	0.024	0.060000	0.048	0.008	2.02	5.79
S201	0.00627	0.003819	60.91	0.004	0.004	0.004	0.008	0.032000	0.028	0.004	3.53	20.05

Table 10-3: Summary Statistics for the Garage Microenvironment

Garage												
Variable	Mean	StDev	CoefVar	Minimum	Q1	Median	Q3	Maximum	Range	IQR	Skewness	Kurtosis
S001	6.32	12.73	201.27	0.34	0.94	2.17	5.95	83.68	83.34	5.01	4.52	22.82
S002	11.23	15.01	133.68	0.5	1.83	5.39	11.81	76.10	75.61	9.98	2.23	5.01
S003	6.571	3.995	60.8	2.31	4.151	5.076	7.486	23.880	21.569	3.335	2.14	5.16
S004	1309	3398	259.59	0	78	206	886	27064	27064	808	5.4	35.71
S005	0.81	1.568	193.68	0.024	0.072	0.173	0.744	10.660	10.636	0.672	3.81	17.99
S006	4.773	5.663	118.64	0	1.512	3.036	5.412	29.384	29.384	3.9	2.42	6.45
S007	4.947	6.719	135.82	0.188	0.756	2.128	5.384	33.407	33.219	4.628	2.22	5.00
S008	25.93	49.05	189.14	3.59	7.94	11.84	25.32	413.25	409.66	17.38	5.89	41.56
S009	0.0691	0.45	651.72	0	0	0	0	4.2320	4.232	0	8.46	76.84
S010	12.18	19.38	159.13	2.38	5.31	7.32	11.83	151.16	148.78	6.52	5.75	36.55
S011	199.7	236.3	118.32	22.4	65.3	115.8	212.1	1351.0	1328.6	146.8	2.68	8.08
S012	1.2694	0.0968	7.63	1.088	1.204	1.2667	1.31	1.7320	0.644	0.106	1.95	7.35
S013	0	0	*	0	0	0	0	0.000000	0	0	*	*
S014	0.02133	0.04299	201.49	0	0	0.004	0.024	0.30000	0.3	0.024	3.75	18.63
S015	0.959	1.647	171.76	0.024	0.096	0.26	0.964	10.940	10.916	0.868	3.31	14.30
S016	7.294	9.567	131.16	0	3.244	4.504	7.204	80.080	80.08	3.96	5.18	34.99
S017	9.45	15.14	160.29	0.24	2.04	4.37	10.33	105.45	105.22	8.29	4.36	22.60
S018	8.94	17.96	200.74	0.03	1.06	3.73	8.57	119.65	119.63	7.52	4.49	22.95
S019	12.95	25.4	196.13	0.03	1.55	5.23	11.7	162.80	162.77	10.15	4.28	20.72
S020	19.05	14.49	76.05	6.37	11.28	14.61	19.69	94.00	87.63	8.42	2.78	8.84
S021	0	0	*	0	0	0	0	0.000000	0	0	*	*
S022	0.014	0.1391	994.99	0	0	0	0	1.3840	1.384	0	9.95	99.00
S023	164.6	341	207.2	2.4	22.6	55	152.1	2156.1	2153.7	129.5	4.25	19.46
S024	61.4	116.3	189.33	1.2	8.4	23.9	53.9	728.5	727.3	45.5	4.16	19.74
S025	11.41	42.49	372.49	0	0	0	0	262.05	262.05	0	4.83	24.47

S026	0.4686	0.4015	85.69	0	0.252	0.384	0.5548	2.1760	2.176	0.3028	1.95	4.80
S027	0.005085	0.003144	61.83	0	0.004	0.004	0.006667	0.020000	0.02	0.002667	2.41	9.28
S028	0.03234	0.01605	49.62	0	0.024	0.028	0.04	0.09000	0.09	0.016	1.82	3.94
S029	2.617	4.151	158.61	0.008	0.3	1.224	3.376	26.007	25.999	3.076	3.81	17.73
S030	0.888	1.074	120.9	0.064	0.284	0.53	1.048	7.800	7.736	0.764	3.66	18.46
S031	0.0214	0.1503	703.28	0	0	0	0	1.1600	1.16	0	7.03	48.84
S032	10	16.61	166.17	0.12	1.51	4.48	10.28	90.17	90.05	8.77	3.39	12.36
S033	4.814	8.941	185.7	0.048	0.628	2.164	5.124	58.207	58.159	4.496	4.31	21.61
S034	9.12	15.91	174.51	0.02	0.9	4.39	10.22	97.69	97.68	9.32	4.02	18.98
S035	19.22	33	171.7	0.04	1.77	9.08	23.13	199.20	199.17	21.36	3.87	17.36
S036	11.14	20.67	185.47	0.04	1.32	4.77	12.66	129.97	129.93	11.34	4.3	21.18
S037	25.39	43.71	172.17	0.06	2.82	10.34	31.51	265.55	265.5	28.69	3.87	17.37
S038	1.865	3.903	209.23	0.012	0.204	0.832	1.767	26.693	26.681	1.563	4.97	27.55
S039	0.0341	0.3393	994.99	0	0	0	0	3.3760	3.376	0	9.95	99.00
S040	0.3195	0.9077	284.09	0	0	0	0.348	6.6840	6.684	0.348	5.16	30.18
S041	2.218	1.288	58.08	0	1.452	1.824	2.52	7.260	7.26	1.068	1.67	2.79
S042	4.361	5.471	125.47	0.756	1.476	2.296	4.416	30.420	29.664	2.94	2.78	8.17
S043	0.698	1.826	261.49	0.012	0.076	0.184	0.47	12.428	12.416	0.394	4.76	24.12
S044	0.2301	0.4869	211.58	0	0	0	0	2.3320	2.332	0	2.4	5.60
S045	80.5	137.1	170.34	0.7	10.7	34.7	78.9	700.7	700	68.3	3.26	10.94
S046	0.3339	0.6351	190.21	0	0	0	0.536	2.7560	2.756	0.536	2.22	4.61
S047	0.0888	0.3217	362.25	0	0	0	0	2.4760	2.476	0	5.31	33.53
S048	0.0673	0.2282	339.02	0	0	0.028	0.056	2.0760	2.076	0.056	7.58	63.73
S049	0.0196	0.1715	874.94	0	0	0	0	1.7000	1.7	0	9.81	97.01
S050	0.3355	0.7634	227.56	0.072	0.132	0.176	0.288	7.1320	7.06	0.156	7.68	66.01
S051	13.73	15.12	110.06	0.56	3.54	8.11	16.99	74.09	73.54	13.45	2.06	4.51
S052	3.82	5.475	143.32	0	0.64	1.696	4.568	34.953	34.953	3.928	3.05	11.88
S053	0	0	*	0	0	0	0	0.000000	0	0	*	*
S054	4.912	7.163	145.82	0.012	0.472	2.32	6.107	40.393	40.381	5.635	2.86	9.91

S055	0.4601	0.604	131.29	0.012	0.076	0.26	0.608	3.3800	3.368	0.532	2.7	8.55
S056	0.00198	0.01409	711.91	0	0	0	0	0.11600	0.116	0	7.28	53.56
S057	0.707	1.331	188.29	0	0	0	1	7.700	7.7	1	3.31	13.88
S058	0.664	1.154	173.74	0.004	0.072	0.336	0.828	7.507	7.503	0.756	4.3	21.70
S059	0.4875	0.8507	174.48	0	0.068	0.264	0.6	5.6533	5.6533	0.532	4.26	21.58
S060	2.085	3.101	148.74	0.008	0.272	1.072	2.58	18.220	18.212	2.308	3.16	12.18
S061	4.441	6.6	148.6	0.024	0.552	1.96	5.34	39.567	39.543	4.788	3.15	12.27
S062	1.99	3.204	161.04	0.004	0.216	1.02	2.484	19.940	19.936	2.268	3.77	17.25
S063	5.083	6.851	134.78	0.076	0.976	2.456	6.008	34.713	34.637	5.032	2.45	6.45
S064	14.7	19.84	134.92	0.08	2.57	7.17	18.54	100.56	100.48	15.97	2.6	7.67
S065	4.169	6.05	145.12	0.012	0.524	2.092	5.512	35.673	35.661	4.988	3.12	12.16
S066	1.78	2.767	155.44	0.008	0.192	0.744	2.052	16.367	16.359	1.86	3.36	13.63
S067	0.3603	0.6858	190.34	0	0.028	0.168	0.42	4.6000	4.6	0.392	4.64	25.21
S068	3.958	6.046	152.75	0.044	0.552	2.116	5.108	37.587	37.543	4.556	3.49	15.01
S069	4.5	21.1	468.88	0.28	0.34	0.52	0.97	143.07	142.79	0.63	5.69	31.67
S070	134.6	240.2	178.48	2.2	17.5	56	143	1344.3	1342	125.5	3.59	13.38
S071	0.29	2.105	726.16	0	0	0	0	18.856	18.856	0	7.96	66.21
S072	0.0973	0.591	607.66	0	0	0	0	4.5200	4.52	0	6.48	42.97
S073	5.62	10.41	185.43	0.04	0.79	2.54	5.67	60.41	60.37	4.88	3.78	15.47
S074	8.75	16.12	184.21	0.04	1.29	4.13	9.23	96.45	96.42	7.94	4.04	17.50
S075	1.407	2.078	147.65	0	0.524	0.896	1.764	18.132	18.132	1.24	5.92	44.12
S076	23.92	36.47	152.46	0.13	4.32	12.77	28.94	198.39	198.26	24.61	3.28	11.93
S077	29.51	41.09	139.25	0.21	5.4	15.4	33.39	212.93	212.72	27.99	2.69	7.97
S078	1.214	1.27	104.57	0.672	0.74	0.79	0.972	8.268	7.596	0.232	3.83	15.36
S079	0.587	1	170.3	0	0	0.196	0.708	4.540	4.54	0.708	2.49	6.21
S080	0.01301	0.08687	667.7	0	0	0	0	0.81600	0.816	0	8.48	76.82
S081	0	0	*	0	0	0	0	0.000000	0	0	*	*
S082	0.3369	0.361	107.12	0	0.176	0.24	0.388	2.8900	2.89	0.212	4.67	28.04
S083	94.6	109.3	115.56	1.2	19.5	49.3	116.1	418.4	417.2	96.7	1.62	1.73

S084	0.053349	0.006819	12.78	0.04	0.048	0.052	0.056	0.080000	0.04	0.008	0.88	1.98
S085	0.001037	0.001901	183.26	0	0	0	0	0.008000	0.008	0	1.52	1.18
S086	0.362	1.901	524.49	0	0.004	0.012	0.02	12.172	12.172	0.016	5.61	30.42
S087	0.00533	0.05105	957.12	0	0	0	0	0.50800	0.508	0	9.94	98.91
S088	0.1348	0.575	426.59	0	0	0	0	3.8480	3.848	0	5.38	30.44
S089	0.5819	0.9187	157.89	0.004	0.064	0.232	0.6133	4.2400	4.236	0.5493	2.65	6.76
S090	0.000444	0.004422	994.99	0	0	0	0	0.044000	0.044	0	9.95	99.00
S091	0.2155	0.5033	233.51	0	0	0	0.24	3.2000	3.2	0.24	3.69	15.69
S092	0.257	2.559	994.99	0	0	0	0	25.460	25.46	0	9.95	99.00
S093	4.838	6.078	125.64	0.088	0.892	2.368	6.1	28.727	28.639	5.208	2.16	4.92
S094	0.988	1.473	149.08	0.004	0.124	0.428	1.02	7.507	7.503	0.896	2.55	6.54
S095	1.115	1.738	155.81	0.008	0.128	0.428	1.116	8.487	8.479	0.988	2.58	6.39
S096	0.02962	0.08224	277.63	0	0	0	0	0.57333	0.57333	0	4.24	21.95
S097	0.1932	0.1327	68.68	0.076	0.108	0.144	0.232	0.7067	0.6307	0.124	2.38	6.06
S098	1.1	1.42	129.05	0	0	0.72	1.74	6.412	6.412	1.74	1.41	1.67
S099	1.296	1.562	120.55	0.056	0.48	0.884	1.612	12.484	12.428	1.132	4.49	27.81
S100	0.1554	0.8365	538.32	0	0	0	0	6.6400	6.64	0	6.27	42.15
S101	0.2491	0.3629	145.69	0	0.064	0.152	0.2653	2.2067	2.2067	0.2013	3.86	16.86
S102	0.923	1.316	142.62	0.012	0.204	0.52	0.944	7.627	7.615	0.74	3.52	14.29
S103	5.372	7.575	141	0.084	1.116	3.252	6.03	45.073	44.989	4.914	3.27	12.18
S104	42.24	67.15	158.97	0.21	6.93	20.94	49.94	377.89	377.69	43.02	3.36	12.29
S105	13.36	16.8	125.75	0.27	3.16	7.63	15.59	86.01	85.74	12.43	2.65	7.86
S106	12.76	15.38	120.54	0.23	2.45	7.53	15.12	71.37	71.14	12.66	2.02	3.69
S107	3.747	6.145	163.99	0.028	0.648	2.024	3.636	35.893	35.865	2.988	3.68	14.88
S108	18.74	64.2	342.67	0.36	1.26	2.9	7.7	460.59	460.23	6.44	5.48	32.25
S109	0	0	*	0	0	0	0	0.000000	0	0	*	*
S110	0.261	0.3515	134.71	0.004	0.064	0.104	0.272	1.8520	1.848	0.208	2.39	5.94
S111	0.5814	0.5298	91.13	0.152	0.348	0.504	0.672	4.9267	4.7747	0.324	6.04	46.99
S112	13	15.77	121.38	0.14	2.43	5.43	17.36	85.87	85.73	14.93	2.04	4.83

S113	45.64	62.68	137.33	0.34	7.35	19.81	53.27	385.28	384.94	45.92	2.73	9.42
S114	16.32	22.4	137.25	0.13	3.08	6.89	20.36	131.58	131.45	17.28	2.61	8.17
S115	0.003293	0.002362	71.72	0	0	0.004	0.004	0.010000	0.01	0.004	-0.01	-0.31
S116	0.00004	0.000402	994.99	0	0	0	0	0.004000	0.004	0	9.95	99.00
S117	0.000121	0.000895	738.59	0	0	0	0	0.008000	0.008	0	7.94	65.80
S118	0.2093	0.3485	166.55	0.008	0.04	0.084	0.212	2.2133	2.2053	0.172	3.68	15.64
S119	1.093	1.599	146.3	0.02	0.216	0.48	1.156	9.633	9.613	0.94	2.99	10.49
S120	0.5355	0.8641	161.36	0.008	0.1	0.22	0.604	5.5200	5.512	0.504	3.39	13.78
S121	0.5681	0.8299	146.08	0.012	0.132	0.276	0.628	5.6000	5.588	0.496	3.49	15.36
S122	0.4419	0.6451	145.98	0.008	0.084	0.2	0.4703	3.9400	3.932	0.3863	2.93	10.23
S123	0.4136	0.8737	211.23	0	0.04	0.104	0.2533	4.4933	4.4933	0.2133	3.14	9.57
S124	0.2675	0.9219	344.67	0	0	0.032	0.084	7.5000	7.5	0.084	5.91	40.91
S125	0.01059	0.07983	754.15	0	0	0	0.004	0.79600	0.796	0.004	9.92	98.54
S126	0.0278	0.01471	52.94	0	0.024	0.028	0.032	0.07600	0.076	0.008	0.89	3.14
S127	0.02307	0.04787	207.49	0	0	0	0	0.20000	0.2	0	2.1	3.58
S128	7.56	11.62	153.67	0	1.18	3.78	8.25	66.21	66.21	7.07	3.26	11.76
S129	2.752	3.911	142.11	0.024	0.568	1.44	3.293	21.807	21.783	2.725	3.19	11.86
S130	0.0185	0.157	846.51	0	0	0	0	1.5360	1.536	0	9.46	91.72
S131	2.033	2.721	133.8	0	0.376	1.148	2.56	15.987	15.987	2.184	3.04	11.06
S132	1.707	2.367	138.66	0.032	0.336	0.956	2.196	13.747	13.715	1.86	3.24	12.40
S133	12.48	15.75	126.18	0.23	2.78	7.27	14.71	79.67	79.43	11.93	2.56	7.23
S134	4.046	5.891	145.6	0.036	0.692	1.808	4.787	38.847	38.811	4.095	3.22	13.53
S135	1.415	2.003	141.53	0.016	0.264	0.656	1.668	13.147	13.131	1.404	3.16	13.09
S136	3.96	5.705	144.07	0.06	0.696	1.828	4.324	35.893	35.833	3.628	2.97	10.98
S137	0.0672	0.1229	182.87	0	0	0	0.1	0.5440	0.544	0.1	2.02	3.55
S138	0.00941	0.0429	455.74	0	0	0	0	0.24400	0.244	0	4.62	20.39
S139	1.679	2.087	124.28	0.016	0.332	0.768	2.356	9.960	9.944	2.024	2.04	4.27
S140	0.14532	0.06313	43.44	0	0.108	0.132	0.164	0.41200	0.412	0.056	1.62	3.68
S141	3.21	4.044	125.98	0.028	0.768	1.52	3.936	22.893	22.865	3.168	2.59	8.01

S142	15.98	20.32	127.15	0.08	4.16	8.24	19.96	103.69	103.61	15.8	2.59	7.64
S143	3.944	5.271	133.65	0.02	0.908	1.892	5.013	29.220	29.2	4.105	2.91	10.04
S144	3.491	4.468	127.97	0.028	0.852	1.772	4.347	24.833	24.805	3.495	2.76	9.07
S145	9.62	12.24	127.15	0.06	2.07	4.8	12.16	66.52	66.46	10.09	2.65	8.21
S146	5.311	6.745	126.99	0.036	1.344	2.72	6.773	33.927	33.891	5.429	2.53	6.87
S147	0.7853	0.9749	124.15	0.016	0.168	0.324	1.052	5.7600	5.744	0.884	2.5	8.19
S148	3.247	4.258	131.13	0.028	0.776	1.6	3.976	23.500	23.472	3.2	2.65	8.01
S149	2.6986	0.5808	21.52	2.304	2.48	2.544	2.64	5.6680	3.364	0.16	3.82	14.74
S150	0.1944	0.595	306.08	0	0	0	0.112	4.0000	4	0.112	4.44	21.81
S151	0.001657	0.006834	412.51	0	0	0	0	0.040000	0.04	0	4.68	22.13
S152	0.00154	0.01113	725.23	0	0	0	0	0.10800	0.108	0	9.17	87.69
S153	0.779	1.225	157.29	0.008	0.148	0.368	0.8	7.700	7.692	0.652	3.56	15.12
S154	1.689	2.395	141.8	0	0.424	0.732	2.1	15.827	15.827	1.676	3.33	14.43
S155	2.327	3.033	130.36	0.124	0.476	1.236	2.632	18.533	18.409	2.156	2.74	9.22
S156	0.04546	0.03432	75.49	0.012	0.02	0.036	0.06	0.19000	0.178	0.04	2.02	4.74
S157	0.2817	0.8709	309.16	0.024	0.032	0.04	0.072	5.5640	5.54	0.04	4.88	24.65
S158	0.00412	0.04101	994.99	0	0	0	0	0.40800	0.408	0	9.95	99.00
S160	0.1265	0.1536	121.4	0.004	0.032	0.072	0.184	0.8533	0.8493	0.152	2.59	8.31
S161	0.6072	0.8082	133.1	0.004	0.14	0.296	0.972	4.5267	4.5227	0.832	2.8	9.53
S162	2.031	2.76	135.88	0.016	0.432	0.987	2.94	15.600	15.584	2.508	2.78	9.25
S163	0.1702	0.2298	134.97	0.004	0.044	0.084	0.204	1.2333	1.2293	0.16	3.02	10.52
S164	0.5545	0.6961	125.54	0.012	0.12	0.268	0.8267	3.7333	3.7213	0.7067	2.39	6.69
S165	0.2986	0.276	92.43	0.008	0.108	0.212	0.39	1.4606	1.4526	0.282	2.01	4.95
S166	0.2002	0.2604	130.07	0.004	0.056	0.096	0.236	1.4133	1.4093	0.18	2.79	8.88
S167	0.01276	0.01705	133.61	0	0	0.008	0.016	0.08000	0.08	0.016	2.07	4.39
S168	1.268	2.192	172.84	0	0.244	0.656	1.264	12.644	12.644	1.02	3.69	14.70
S169	0.1516	0.2707	178.6	0	0	0.016	0.16	1.3120	1.312	0.16	2.45	5.97
S170	3.131	7.902	252.37	0	0.036	0.436	1.92	51.068	51.068	1.884	4.08	18.65
S171	0.3492	0.527	150.94	0.028	0.124	0.212	0.372	4.3014	4.2734	0.248	5.7	37.93

S172	1.7605	0.3215	18.26	1.34	1.564	1.66	1.864	3.1000	1.76	0.3	1.73	3.30
S173	0.0461	0.415	900.99	0	0	0	0	4.1280	4.128	0	9.91	98.45
S175	0.2154	0.3233	150.09	0	0.048	0.096	0.244	1.8067	1.8067	0.196	3.13	10.76
S176	3.087	4.217	136.58	0.136	0.532	1.393	4.04	27.744	27.608	3.508	2.97	12.27
S177	0.010838	0.008571	79.08	0	0.006667	0.008	0.012	0.056000	0.056	0.005333	2.78	10.10
S178	0.010448	0.009808	93.87	0	0.004	0.008	0.012	0.064000	0.064	0.008	3.1	11.93
S179	0.331	1.051	317.03	0.016	0.036	0.056	0.088	6.412	6.396	0.052	4.4	19.68
S180	0.44765	0.06792	15.17	0.244	0.4	0.444	0.512	0.56800	0.324	0.112	-0.28	-0.32
S181	0.02482	0.08519	343.22	0	0	0	0.016	0.51333	0.51333	0.016	4.93	24.36
S183	4.1	12.15	295.91	0.06	0.43	1.11	2.78	88.14	88.08	2.35	5.71	34.26
S184	0.03469	0.04568	131.68	0	0.012	0.02	0.036	0.24000	0.24	0.024	3.05	10.18
S185	0.0229	0.2179	949.29	0	0	0	0	2.1680	2.168	0	9.94	98.87
S186	0.3602	0.5078	140.97	0.044	0.072	0.1667	0.328	2.3120	2.268	0.256	2.28	4.54
S187	0.01127	0.0704	624.52	0	0	0	0	0.53600	0.536	0	6.93	47.66
S188	1.785	8.74	489.77	0	0.124	0.316	0.676	80.096	80.096	0.552	8.06	69.09
S189	0.11668	0.01438	12.32	0.104	0.112	0.116	0.12	0.24800	0.144	0.008	7.88	72.49
S190	0.036275	0.008851	24.4	0.028	0.032	0.032	0.036	0.070000	0.042	0.004	2.53	6.75
S191	0.03586	0.03346	93.3	0.008	0.016	0.028	0.04	0.22400	0.216	0.024	3.12	12.43
S193	0.57954	0.04173	7.2	0.504	0.556	0.57333	0.596	0.72400	0.22	0.04	1.55	3.43
S194	0.000909	0.002181	239.91	0	0	0	0	0.010000	0.01	0	2.48	5.58
S195	0.000121	0.001206	994.99	0	0	0	0	0.012000	0.012	0	9.95	99.00
S197	0.00495	0.001987	40.13	0	0.004	0.004	0.006667	0.012000	0.012	0.002667	1.13	1.70
S200	0.020664	0.005575	26.98	0.012	0.016	0.02	0.024	0.036000	0.024	0.008	0.59	-0.10
S201	0.006533	0.003915	59.93	0.004	0.004	0.004	0.008	0.020000	0.016	0.004	1.89	3.34

11 Appendix D: Comparison of Summary Statistics Amongst Canadian Studies

Table 11-1: Comparison of Summary Statistics amongst Canadian Indoor and Outdoor Microenvironments

	ID	VOC	Indoor				Outdoor				I/O median
			Mean	Median	Min	Max	Mean	Median	Min	Max	
RAGI (Ottawa)	S003	Ethane	20.3	12.1	4.1	132.3	3.9	3.8	1.6	7.7	3.2
	S004	Methanol	308.2	170.1	43.1	3736.3	22.2	13.1	0.0	93.1	13.0
	S008	Acetaldehyde	43.1	26.0	4.9	596.6	9.0	6.7	2.7	99.5	3.9
	S010	Propane	25.6	9.9	3.6	222.4	3.6	3.3	1.8	6.9	3.0
	S011	Ethanol	945.5	622.9	39.8	3242.5	4.8	3.9	0.3	27.8	160.4
	S012	Chloromethane	1.4	1.3	1.2	2.0	1.3	1.3	1.1	1.5	1.1
	S015	1,3-Butadiene	0.2	0.1	0.0	1.0	0.0	0.0	0.0	0.1	3.2
	S019	<i>trans</i> -2-Butene	2.2	0.7	0.1	25.4	0.1	0.0	0.0	0.5	15.4
	S020	Acetone	63.8	42.7	10.5	496.4	7.5	6.1	2.4	63.9	7.0
	S023	Butane	53.4	15.6	2.8	591.2	3.0	2.1	1.1	14.1	7.5
	S024	Isobutane	53.1	15.6	1.7	665.5	1.5	1.0	0.5	7.8	15.7
	S030	Isoprene	3.3	2.9	0.5	10.9	0.0	0.0	0.0	0.1	104.1
	S035	<i>trans</i> -2-Pentene	3.9	0.9	0.1	59.1	0.1	0.0	0.0	0.3	20.9
	S051	Benzene	4.1	2.2	0.7	32.9	0.7	0.6	0.3	1.4	3.7
	S075	2-Methylpentane	2.5	1.7	0.1	23.2	0.8	0.4	0.1	21.4	3.9
	S079	Ethyl acetate	10.4	6.6	0.0	118.6	0.1	0.1	0.0	0.4	74.5
	S083	Toluene	27.7	11.9	2.0	359.5	1.0	0.7	0.3	2.9	16.1
	S097	1,2-Dichloroethane	0.5	0.2	0.1	7.4	0.1	0.1	0.1	0.1	2.2
	S111	Benzaldehyde	1.4	1.1	0.0	5.2	0.3	0.2	0.1	3.0	5.1
	S112	Ethylbenzene	8.1	1.5	0.3	215.5	0.1	0.1	0.0	0.4	12.7
	S113	<i>m</i> -, <i>p</i> -Xylene	26.7	4.9	1.0	720.6	0.4	0.3	0.1	1.2	15.7

Edmonton	S114	<i>o</i> -Xylene	9.4	1.8	0.4	264.2	0.2	0.1	0.0	0.4	14.1
	S140	Chloroform	1.0	0.8	0.1	3.5	0.1	0.1	0.1	0.2	10.0
	S141	1,2,3-Trimethylbenzene	1.9	0.6	0.0	36.5	0.0	0.0	0.0	0.1	21.8
	S142	1,2,4-Trimethylbenzene	5.8	2.3	0.6	97.6	0.1	0.1	0.0	0.5	17.7
	S143	1,3,5-Trimethylbenzene	1.6	0.6	0.1	28.5	0.0	0.0	0.0	0.1	17.9
	S145	3-Ethyltoluene	3.1	1.3	0.3	51.4	0.1	0.1	0.0	0.3	16.0
	S149	Freon 12	3.0	2.7	2.2	6.5	2.6	2.6	2.3	2.8	1.0
	S156	Trichloroethene (TCE)	0.2	0.1	0.0	2.5	0.0	0.0	0.0	0.2	2.7
	S168	<i>a</i> -Pinene	13.9	5.2	0.0	140.5	0.1	0.0	0.0	0.4	216.3
	S169	<i>b</i> -Pinene	1.3	0.4	0.0	22.5	0.0	0.0	0.0	0.2	ERR
	S170	Limonene	26.3	12.5	0.0	322.9	0.0	0.0	0.0	0.6	780.6
	S171	Camphene	1.6	0.7	0.1	15.7	0.0	0.0	0.0	0.2	15.5
	S179	1,4-Dichlorobenzene	3.1	0.1	0.0	77.0	0.0	0.0	0.0	0.3	2.8
	S186	Tetrachloroethene (PERC)	3.2	0.5	0.1	66.9	0.1	0.1	0.0	1.1	8.0
	S188	Dodecane	2.4	0.9	0.0	21.5	0.1	0.0	0.0	0.5	26.3
	S003	Ethane	34.0	78.0	1.2	1466.0	8.4	12.7	2.8	306.0	6.1
	S004	Methanol	134.0	197.0	12.0	2550.0	14.2	23.3	1.7	231.0	8.5
	S008	Acetaldehyde	18.8	24.6	3.0	88.0	3.3	4.1	0.9	22.0	6.0
	S010	Propane	20.0	46.0	1.6	383.0	7.3	10.9	1.1	93.0	4.2
	S011	Ethanol	681.0	1057.0	4.9	22756.0	4.0	7.6	0.1	648.0	139.1
	S012	Chloromethane	1.4	1.5	1.1	9.0	1.2	1.2	1.0	1.4	1.3
	S015	1,3-Butadiene	0.1	0.3	0.0	15.0	0.1	0.1	0.0	0.7	2.3
	S019	<i>trans</i> -2-Butene	0.1	0.3	0.0	4.3	0.1	0.1	0.0	1.1	3.1
	S020	Acetone	75.0	139.0	5.7	1474.0	3.6	4.5	1.5	100.0	30.9
	S023	Butane	12.4	27.2	0.4	11.0	5.3	8.7	0.5	111.0	3.1
	S024	Isobutane	15.2	57.0	0.1	1171.0	2.6	4.6	0.3	91.0	12.4
	S030	Isoprene	3.9	4.6	0.1	24.0	0.1	0.1	0.0	3.0	51.1

	S035	<i>trans</i> -2-Pentene	0.2	0.5	0.0	5.9	0.1	0.1	0.0	1.1	4.4
	S051	Benzene	1.2	1.7	0.4	10.0	0.8	1.0	2.7	3.9	1.8
	S075	2-Methylpentane	1.9	3.2	0.0	100.0	0.7	1.1	0.0	5.5	2.9
	S079	Ethyl acetate	5.4	8.3	0.1	108.0	0.1	0.3	0.0	19.0	28.6
	S083	Toluene	7.6	18.3	0.4	383.0	1.3	2.5	0.1	64.0	7.3
	S097	1,2-Dichloroethane	0.2	0.7	0.7	6.5	0.1	0.1	0.1	0.2	8.8
	S111	Benzaldehyde	1.9	2.1	0.3	37.0	0.1	0.2	0.0	1.7	12.4
	S112	Ethylbenzene	1.5	10.7	0.2	552.0	0.3	1.2	0.0	147.0	8.9
	S113	<i>m</i> -, <i>p</i> -Xylene	4.6	34.0	0.0	1356.0	0.9	3.7	0.0	362.0	9.2
	S114	<i>o</i> -Xylene	1.5	5.7	0.2	211.0	0.3	1.2	0.0	134.0	4.8
	S140	Chloroform	0.7	1.1	0.0	14.0	0.1	0.1	0.1	0.3	13.8
	S141	1,2,3-Trimethylbenzene	0.4	2.6	0.0	183.0	0.1	0.1	0.0	0.8	28.9
	S142	1,2,4-Trimethylbenzene	1.4	5.7	0.2	327.0	0.2	0.4	0.0	3.2	14.6
	S143	1,3,5-Trimethylbenzene	0.4	1.5	0.1	90.0	0.1	0.1	0.0	0.9	13.6
	S145	3-Ethyltoluene	0.7	2.2	0.1	106.0	0.1	0.3	0.0	2.1	8.5
	S149	Freon 12	2.5	3.1	0.1	23.0	2.5	2.5	1.9	3.3	1.2
	S156	Trichloroethene (TCE)	0.1	0.2	0.0	3.6	0.0	0.1	0.0	0.9	4.6
	S168	a-Pinene	4.7	8.0	0.4	72.0	0.1	0.2	0.0	2.8	53.3
	S169	b-Pinene	1.8	2.8	0.1	23.0	0.0	0.1	0.0	2.8	46.7
	S170	Limonene	31.0	47.0	0.1	365.0	0.1	0.6	0.0	112.0	82.5
	S171	Camphene	0.5	0.7	0.1	3.9	0.0	0.0	0.0	0.5	17.0
	S179	1,4-Dichlorobenzene	0.1	0.1	0.0	0.5	0.0	0.0	0.0	0.4	3.0
	S186	Tetrachloroethene (PERC)	0.4	1.4	0.1	31.0	0.1	0.2	0.0	1.6	5.8
	S188	Dodecane	1.5	4.6	0.2	196.0	0.1	0.2	0.0	11.0	30.7
Regina	S003	Ethane	35.1	16.9	4.3	692.3	7.3	5.3	2.6	141.1	3.2
	S004	Methanol	138.8	99.6	21.8	913.8	11.6	6.3	2.1	99.6	15.9
	S008	Acetaldehyde	30.0	20.6	6.8	157.4	4.8	3.3	1.3	39.2	6.2

S010	Propane	44.0	21.3	4.8	712.9	6.6	4.5	1.9	40.1	4.8
S011	Ethanol	1236.6	753.4	27.9	10279.0	10.8	3.3	0.2	418.2	228.9
S012	Chloromethane	1.8	1.3	0.8	12.5	1.1	1.1	0.9	1.3	1.3
S015	1,3-Butadiene	0.5	0.2	0.0	5.8	0.1	0.1	0.0	0.5	2.9
S019	<i>trans</i> -2-Butene	1.0	0.2	0.1	35.3	0.1	0.1	0.1	0.7	3.9
S020	Acetone	48.5	36.5	8.6	436.9	4.1	3.4	0.6	36.0	10.8
S023	Butane	54.7	15.5	3.2	948.0	4.5	4.0	1.0	17.5	3.8
S024	Isobutane	68.4	22.5	2.1	526.4	3.0	1.9	0.5	45.8	12.1
S030	Isoprene	5.7	4.3	0.6	48.2	0.1	0.0	0.0	0.9	97.5
S035	<i>trans</i> -2-Pentene	1.1	0.2	0.0	39.6	0.1	0.1	0.0	0.6	3.1
S051	Benzene	2.1	1.2	0.5	17.9	0.8	0.6	0.3	2.7	2.1
S075	2-Methylpentane	3.1	1.2	0.3	72.8	0.7	0.5	0.1	2.7	2.5
S079	Ethyl acetate	11.7	4.1	0.0	197.3	0.4	0.0	0.0	17.2	147.5
S083	Toluene	21.3	7.8	0.0	625.2	1.7	1.0	0.2	14.8	7.9
S097	1,2-Dichloroethane	0.3	0.1	0.0	6.4	0.1	0.1	0.0	0.1	2.1
S111	Benzaldehyde	1.4	1.1	0.1	7.9	0.1	0.1	0.0	0.6	17.8
S112	Ethylbenzene	1.9	1.1	0.2	14.3	0.3	0.2	0.0	1.2	5.9
S113	<i>map</i> -Xylene	6.0	2.9	0.0	42.8	0.8	0.5	0.0	4.1	5.6
S114	<i>o</i> -Xylene	1.8	1.0	0.2	13.5	0.3	0.2	0.0	1.3	5.4
S140	Chloroform	2.2	1.9	0.3	7.1	0.1	0.1	0.1	1.1	25.3
S141	1,2,3-Trimethylbenzene	0.6	0.3	0.0	5.5	0.0	0.0	0.0	0.3	14.9
S142	1,2,4-Trimethylbenzene	1.8	1.0	0.2	14.2	0.2	0.1	0.0	1.4	7.5
S143	1,3,5-Trimethylbenzene	0.5	0.3	0.0	4.1	0.1	0.0	0.0	0.4	7.2
S145	3-Ethyltoluene	0.9	0.5	0.1	8.0	0.1	0.1	0.0	0.7	6.4
S149	Freon 12	4.3	2.9	2.2	88.9	2.8	2.8	2.1	4.0	1.0
S156	Trichloroethene (TCE)	0.2	0.1	0.1	13.2	0.1	0.1	0.1	0.2	1.0
S168	α -Pinene	10.2	3.1	0.0	156.5	0.1	0.0	0.0	0.6	65.5

Windsor	S169	b-Pinene	1.2	0.4	0.0	15.1	0.0	0.0	0.0	0.1	24.0
	S170	Limonene	29.1	15.9	0.0	440.2	0.1	0.0	0.0	3.0	360.7
	S171	Camphene	1.1	0.4	0.1	37.2	0.1	0.1	0.1	0.3	4.4
	S179	1,4-Dichlorobenzene	11.9	0.2	0.0	1111.6	0.2	0.0	0.0	7.4	7.4
	S186	Tetrachloroethene (PERC)	1.6	0.3	0.0	58.0	0.1	0.0	0.0	0.5	8.0
	S188	Dodecane	6.4	5.0	0.4	31.9	1.8	0.7	0.0	27.4	6.9
	S003	Ethane	24.4	14.3	3.0	136.2	4.5	4.3	2.6	8.1	3.3
	S004	Methanol	77.9	63.5	16.8	614.9	6.0	4.5	1.0	39.2	14.0
	S008	Acetaldehyde	15.3	12.6	4.0	78.4	3.1	2.4	1.0	20.3	5.3
	S010	Propane	44.1	17.1	2.4	607.3	3.3	3.1	1.2	9.5	5.6
	S011	Ethanol	809.1	548.5	32.5	4648.3	6.4	3.9	0.0	213.9	141.8
	S012	Chloromethane	1.2	1.2	0.7	2.1	1.1	1.1	0.9	1.3	1.1
	S015	1,3-Butadiene	0.1	0.1	0.0	1.0	0.1	0.0	0.0	0.2	2.1
	S019	<i>trans</i> -2-Butene	0.4	0.2	0.2	6.4	0.2	0.2	0.2	0.2	1.0
	S020	Acetone	78.8	48.0	8.6	1380.7	3.6	3.0	1.2	27.2	15.9
	S023	Butane	44.1	11.7	1.8	687.8	3.7	3.1	0.7	12.0	3.7
	S024	Isobutane	69.6	21.6	1.8	827.8	1.3	1.1	0.4	4.0	20.1
	S030	Isoprene	3.1	2.8	0.4	9.8	0.0	0.0	0.0	0.1	230.4
	S035	<i>trans</i> -2-Pentene	0.4	0.1	0.0	7.7	0.0	0.0	0.0	0.3	2.9
	S051	Benzene	1.6	1.2	0.5	10.4	0.8	0.8	0.4	1.9	1.5
	S075	2-Methylpentane	2.9	1.2	0.3	26.4	0.5	0.3	0.1	8.5	3.7
	S079	Ethyl acetate	8.8	4.8	0.3	148.7	0.1	0.1	0.0	2.2	55.9
	S083	Toluene	15.7	8.3	1.8	130.7	2.7	1.9	0.3	27.4	4.4
	S097	1,2-Dichloroethane	0.2	0.1	0.0	4.3	0.0	0.0	0.0	0.1	2.6
	S111	Benzaldehyde	4.0	1.7	0.0	449.2	0.2	0.1	0.0	1.8	11.4
	S112	Ethylbenzene	10.7	1.2	0.3	1198.5	0.4	0.3	0.0	4.8	4.0
	S113	<i>m, p</i> -Xylene	30.4	3.1	0.7	3431.2	1.1	0.8	0.0	15.3	3.8

S114	<i>o</i> -Xylene	8.0	1.0	0.2	937.4	0.3	0.3	0.0	3.5	4.0
S140	Chloroform	1.1	0.8	0.1	8.6	0.0	0.0	0.0	0.1	19.9
S141	1,2,3-Trimethylbenzene	0.8	0.5	0.0	8.3	0.1	0.1	0.0	0.3	7.9
S142	1,2,4-Trimethylbenzene	2.3	1.5	0.3	16.0	0.3	0.2	0.0	2.8	6.1
S143	1,3,5-Trimethylbenzene	0.6	0.4	0.1	4.1	0.1	0.1	0.0	0.7	5.8
S145	3-Ethyltoluene	1.1	0.7	0.2	14.3	0.2	0.1	0.0	1.2	4.7
S149	Freon 12	4.7	2.7	2.1	164.3	2.9	2.9	2.2	3.4	0.9
S156	Trichloroethene (TCE)	0.1	0.1	0.1	3.0	0.1	0.1	0.1	0.3	1.0
S168	α -Pinene	12.2	5.0	0.4	224.4	0.1	0.0	0.0	0.3	151.9
S169	β -Pinene	2.2	1.1	0.0	32.6	0.0	0.0	0.0	0.1	42.6
S170	Limonene	22.7	13.8	0.1	199.1	0.1	0.1	0.1	0.4	255.7
S171	Camphene	0.5	0.3	0.1	7.8	0.1	0.1	0.1	0.1	3.7
S179	1,4-Dichlorobenzene	0.3	0.1	0.0	3.6	0.0	0.0	0.0	0.2	6.8
S186	Tetrachloroethene (PERC)	0.9	0.2	0.1	46.3	0.1	0.1	0.1	0.5	1.8
S188	Dodecane	1.8	1.3	0.4	13.1	0.2	0.1	0.0	1.4	11.6

12 Appendix E: Comparison of Summary Statistics for International Studies

Table 12-1: RAGI summary stats compared to Dodson et al. (2008)

	VOC	Indoor	Outdoor	Garage	Other		
		Mean	Mean	Mean	I/O Mean	G/O Mean	G/I Mean
RAGI	1,3-Butadiene	0.2	0.0	1.0	3.9	19.9	5.1
	1,4-Dichlorobenzene	3.1	0.0	0.3	63.8	6.7	0.1
	Acetaldehyde	43.1	9.0	25.9	4.8	2.9	0.6
	a-Pinene	13.9	0.1	1.3	254.9	23.3	0.1
	Benzene	4.1	0.7	13.7	6.0	20.4	3.4
	Chloroform	1.0	0.1	0.1	11.1	1.6	0.1
	d-Limonene	26.3	0.0	3.1	628.6	74.9	0.1
	Ethylbenzene	8.1	0.1	13.0	57.4	91.9	1.6
	m, p-Xylene	26.7	0.4	45.6	67.6	115.6	1.7
	MTBE	0.0	0.0	0.0	27.6	55.8	2.0
	o-Xylene	9.4	0.2	16.3	62.5	108.1	1.7
	Styrene	0.3	0.0	0.3	18.1	15.8	0.9
	Tetrachloroethene	3.2	0.1	0.4	27.7	3.1	0.1
	Toluene	27.7	1.0	94.6	27.3	93.1	3.4
	Trichloroethene	0.2	0.0	0.0	4.1	1.2	0.3
Dodson	1,3-Butadiene	0.5	0.3	7.4	2.0	27.4	13.7
	1,4-Dichlorobenzene	3.1	0.3	2.3	11.9	8.8	0.7
	Acetaldehyde	13.0	5.6	8.9	2.3	1.6	0.7
	a-Pinene	11.0	0.4	38.0	26.2	90.5	3.5
	Benzene	2.6	0.9	58.0	3.0	65.9	22.3

Chloroform	1.2	0.1	0.1	17.1	1.1	0.1
d-Limonene	17.0	0.2	7.3	73.9	31.7	0.4
Ethylbenzene	2.4	0.4	35.0	5.7	83.3	14.6
m, p-Xylene	7.3	1.3	90.0	5.6	69.2	12.3
MTBE	7.6	1.2	131.0	6.3	109.2	17.2
o-Xylene	2.6	0.5	35.0	5.5	74.5	13.5
Styrene	1.1	0.1	3.4	11.0	34.0	3.1
Tetrachloroethene	1.9	0.5	2.8	4.1	6.1	1.5
Toluene	13.0	2.3	102.0	5.7	44.3	7.8
Trichloroethene	0.6	0.1	3.3	4.7	25.4	5.4

Table 12-2: RAGI summary stats compared to Batterman et al. (2007)

	VOC	Indoor		Outdoor		Garage		Other		
		Mean	Maximum	Mean	Maximum	Mean	Maximum	I/O Mean	G/O Mean	G/I Mean
RAGI	1,1,1-Trichloroethane	1.57	47.30	0.03	0.06	0.28	5.56	51.6	9.3	0.2
	1,2,3-Trimethyl benzene	1.86	36.52	0.03	0.12	3.21	22.89	54.6	94.5	1.7
	1,2,4-Trimethylbenzene	5.81	97.63	0.15	0.51	15.98	103.69	39.7	109.2	2.8
	1,3,5-Trimethylbenzene	1.59	28.55	0.04	0.13	3.94	29.22	43.5	108.1	2.5
	4-Ethyl toluene	1.60	26.39	0.05	0.17	5.31	33.93	30.8	102.2	3.3
	a-Pinene	13.85	140.48	0.05	0.39	1.27	12.64	254.9	23.3	0.1
	Benzene	4.05	32.90	0.67	1.38	13.73	74.09	6.0	20.4	3.4
	Carbontetrachloride	0.48	0.87	0.46	0.58	0.45	0.57	1.0	1.0	0.9
	Chloroform	1.00	3.45	0.09	0.16	0.15	0.41	11.1	1.6	0.1
	Decane	10.35	222.16	0.07	0.30	3.09	27.74	142.9	42.6	0.3
	Dodecane	2.42	21.45	0.05	0.45	1.79	80.10	44.3	32.7	0.7
	Ethylbenzene	8.13	215.45	0.14	0.38	13.00	85.87	57.4	91.9	1.6
	Heptane	6.08	229.79	0.21	0.57	12.76	71.37	28.4	59.5	2.1
	Limonene	26.27	322.92	0.04	0.59	3.13	51.07	628.6	74.9	0.1
	m, p-Xylene	26.70	720.60	0.39	1.20	45.64	385.28	67.6	115.6	1.7
	Methyl cyclohexane	1.86	24.27	0.08	0.38	4.84	28.73	22.4	58.3	2.6
	Naphthalene	2.84	61.63	0.11	0.69	1.69	15.83	26.4	15.7	0.6
	Nonane	3.40	66.33	0.06	0.23	2.33	18.53	59.0	40.4	0.7
	Octane	1.24	16.57	0.07	0.22	3.96	35.89	17.8	57.0	3.2
	o-Xylene	9.44	264.15	0.15	0.40	16.32	131.58	62.5	108.1	1.7
	Styrene	0.30	1.32	0.02	0.08	0.26	1.85	18.1	15.8	0.9
	Tetrachloroethene	3.24	66.92	0.12	1.10	0.36	2.31	27.7	3.1	0.1

	Toluene	27.73	359.45	1.02	2.87	94.60	418.40	27.3	93.1	3.4
	Undecane	10.81	215.75	0.08	0.42	4.10	88.14	134.7	51.1	0.4
Batterman et al. (2007)	1,1,1-Trichloroethane	5.40	75.40	0.00	0.00	1.30	5.00			0.2
	1,2,3-Trimethyl benzene	1.00	2.70	0.10	0.20	10.30	32.50	10.0	103.0	10.3
	1,2,4-Trimethylbenzene	3.70	15.90	0.30	0.40	44.00	138.90	12.3	146.7	11.9
	1,3,5-Trimethylbenzene	1.10	4.30	0.10	0.20	12.40	38.30	11.0	124.0	11.3
	4-Ethyl toluene	4.60	18.90	0.30	0.40	43.20	131.30	15.3	144.0	9.4
	α -Pinene	14.10	93.70	0.30	0.50	6.80	41.00	47.0	22.7	0.5
	Benzene	2.00	7.60	0.40	0.60	36.60	159.30	5.0	91.5	18.3
	Carbontetrachloride	1.40	5.60	0.90	1.40	1.30	2.60	1.6	1.4	0.9
	Chloroform	0.30	0.90	0.00	0.00	0.00	0.00			0.0
	Decane	2.50	11.40	0.10	0.70	3.90	15.00	25.0	39.0	1.6
	Dodecane	0.70	2.70	0.00	0.00	1.20	6.80			1.7
	Ethylbenzene	2.30	5.20	0.20	0.40	28.00	91.10	11.5	140.0	12.2
	Heptane	2.80	8.20	0.00	0.00	18.80	57.20			6.7
	Limonene	25.60	93.00	0.10	0.30	6.50	16.90	256.0	65.0	0.3
	<i>m, p</i> -Xylene	8.30	21.30	0.70	1.00	114.00	371.10	11.9	162.9	13.7
	Methyl cyclohexane	0.70	1.90	0.00	0.10	6.70	18.00			9.6
	Naphthalene	8.30	91.70	0.00	0.00	8.90	34.40			1.1
	Nonane	1.30	6.40	0.10	0.60	3.60	8.90	13.0	36.0	2.8
	Octane	0.90	1.70	0.00	0.00	6.30	20.80			7.0
	<i>o</i> -Xylene	2.90	7.90	0.20	0.30	38.00	123.90	14.5	190.0	13.1
	Styrene	1.00	7.30	0.00	0.00	0.60	2.80			0.6
	Tetrachloroethene	0.60	4.40	0.00	0.00	0.30	1.60			0.5
	Toluene	26.50	87.00	1.20	1.80	214.30	729.10	22.1	178.6	8.1
	Undecane	1.90	6.30	0.00	0.40	2.70	13.60			1.4

Table 12-3: RAGI summary stats compared to Jia et al. (2008)

	Compound	Indoors		Outdoors		I/O Mean
		Mean	Max	Mean	Max	
RAGI	1,2-Dichloroethane	0.5	7.4	0.1	0.1	6.6
	1,3,5-TMB	1.6	28.5	0.0	0.1	43.5
	4-Ethyltoluene	1.6	26.4	0.1	0.2	30.8
	a-Pinene	13.9	140.5	0.1	0.4	254.9
	Benzene	4.1	32.9	0.7	1.4	6.0
	Chloroform	1.0	3.5	0.1	0.2	11.1
	Cyclohexane	1.2	15.4	0.1	0.2	15.6
	Cymene	1.6	10.0	0.0	0.1	120.0
	d-Limonene	26.3	322.9	0.0	0.6	628.6
	Decane	10.4	222.2	0.1	0.3	142.9
	Dibromochloromethane	0.0	0.0	0.0	0.0	3.1
	Dodecane	2.4	21.5	0.1	0.5	44.3
	Ethylbenzene	8.1	215.5	0.1	0.4	57.4
	Heptane	6.1	229.8	0.2	0.6	28.4
	MIBK	0.5	2.0	0.1	1.6	6.5
	Naphthalene	2.8	61.6	0.1	0.7	26.4
	Nonane	3.4	66.3	0.1	0.2	59.0
	o-Xylene	9.4	264.2	0.2	0.4	62.5
	Octane	1.2	16.6	0.1	0.2	17.8
	m-, p-Xylene	26.7	720.6	0.4	1.2	67.6
	Styrene	0.3	1.3	0.0	0.1	18.1
	Tetrachloroethene	3.2	66.9	0.1	1.1	27.7
	Toluene	27.7	359.5	1.0	2.9	27.3
	Trichloroethene	0.2	2.5	0.0	0.2	4.1

Jia et al. (2008)	Undecane	10.8	215.8	0.1	0.4	134.7
	1,2-Dichloroethane	0.0	0.1	0.0	0.3	
	1,3,5-TMB	0.9	27.3	0.2	2.8	4.0
	4-Ethyltoluene	3.9	61.6	0.8	8.3	5.1
	α -Pinene	9.0	139.2	0.2	2.4	45.2
	Benzene	2.8	47.4	1.1	4.4	2.5
	Chloroform	0.7	14.6	0.1	2.5	10.3
	Cyclohexane	0.5	26.8	0.0	1.8	46.0
	Cymene	1.8	38.0	0.0	2.0	46.0
	<i>d</i> -Limonene	25.7	258.5	0.5	12.7	56.0
	Decane	5.3	404.1	0.2	5.6	25.3
	Dibromochloromethane	0.1	1.1	0.0	0.3	
	Dodecane	1.1	54.6	0.0	0.3	37.3
	Ethylbenzene	2.2	79.9	0.5	6.7	4.2
	Heptane	4.2	303.4	0.4	5.7	10.0
	MIBK	1.6	332.2	0.0	2.4	78.0
	Naphthalene	3.5	91.8	0.3	4.7	12.5
	Nonane	2.8	126.5	0.2	2.3	13.9
	<i>o</i> -Xylene	2.4	50.4	0.6	7.9	3.8
	Octane	1.4	43.5	0.2	1.1	7.6
	<i>m</i> -, <i>p</i> -Xylene	7.9	318.7	2.0	31.4	4.0
	Styrene	0.5	6.6	0.0	0.5	12.8
	Tetrachloroethene	0.9	27.8	0.3	3.1	2.9
	Toluene	15.6	197.3	2.6	21.6	6.0
	Trichloroethene	0.1	2.0	0.0	0.2	2.0
	Undecane	3.4	177.1	0.1	1.9	34.0

Table 12-4: RAGI summary stats compared to Edwards et al. (2001)

	Compound	Indoor		Outdoor		Other
		Mean	Max	Mean	Max	I/O Mean
RAGI	a-pinene	14	140	0	0	255
	Benzaldehyde	1	5	0	3	5
	Benzene	4	33	1	1	6
	Cyclohexane	1	15	0	0	16
	Decane	10	222	0	0	143
	d-limonene	26	323	0	1	629
	Ethylbenzene	8	215	0	0	57
	Hexane	6	84	0	1	17
	<i>m</i> -, <i>p</i> -xylene	27	721	0	1	68
	Napthalene	3	62	0	1	26
	Nonane	3	66	0	0	59
	o-xylene	9	264	0	0	63
	Styrene	0	1	0	0	18
	Tetrachloroethene	3	67	0	1	28
	Toluene	28	359	1	3	27
	Trichloroethene	0	3	0	0	4
	Undecane	11	216	0	0	135
Edwards	a-pinene	16	216	2	41	8
	Benzaldehyde	5	17	3	9	2
	Benzene	2	14	2	8	1
	Cyclohexane	0	27	0	100	
	Decane	5	128	1	34	5
	<i>d</i> -limonene	32	495	0	12	
	Ethylbenzene	3	19	1	7	3
	Hexane	0	54	5	458	0

<i>m</i> -, <i>p</i> -xylene	8	62	3	18	3
Napthalene	1	4	0	1	
Nonane	2	48	1	30	2
<i>o</i> -xylene	2	24	1	7	2
Styrene	1	15	0	7	
Tetrachloroethene	0	39	0	0	
Toluene	20	247	6	132	4
Trichloroethene	0	41	0	0	
Undecane	5	84	1	17	7

13 Appendix F: Summation Variable Concentrations in each Microenvironment

Table 13-1: Summation Variable Concentrations in each Microenvironment

SAMPLE ID	SUM81			TVOC			BTEX			SUM15CEPA		
	Outdoor	Indoor	Garage	Outdoor	Indoor	Garage	Outdoor	Indoor	Garage	Outdoor	Indoor	Garage
02-1	108.4	353.2	513.3	118.9	370.2	555.2	4.6	14.3	61.4	16.2	25.5	15.7
02-2	136.6	559.9	567.2	146.3	578.8	615.1	6.1	23.2	100.4	17.0	40.1	23.0
02-3	77.6	589.5	376.0	86.8	604.9	413.4	1.4	17.4	77.0	22.6	28.9	21.3
03-1	42.3	379.8	1815.5	46.5	418.2	2278.7	1.1	31.4	501.6	8.4	24.1	63.6
03-2	87.5	402.0	1843.8	99.2	457.0	2230.3	3.6	45.5	425.9	31.5	23.5	67.7
03-3	42.6	319.9	2038.8	48.4	357.9	2503.1	1.2	36.1	554.0	9.0	20.3	74.6
06-1	147.8	4093.8	2238.6	152.6	4180.8	2684.7	3.2	40.6	178.7	21.5	117.6	43.4
06-2	162.8	3273.4	2185.5	173.6	3382.4	2861.2	5.5	59.3	265.1	10.5	147.0	53.6
06-3	50.8	4111.6	2656.0	57.8	4271.1	3425.4	1.9	69.2	319.6	7.8	132.7	70.2
08-1	62.0		470.0	67.5		543.6	0.9		42.5	21.6		24.1
08-2	74.3	914.8	510.7	83.2	991.9	600.5	2.0	7.7	55.3	23.1	74.2	29.7
08-3	47.2	835.6	488.5	57.4	927.5	578.4	1.9	8.9	62.6	10.9	108.4	44.4
10-1	110.8	1149.5	3542.3	118.2	1214.3	3896.4	1.5	24.0	220.1	36.7	68.8	52.0
10-2	70.7	1280.4	2633.2	76.1	1351.2	2985.8	1.7	38.1	184.9	19.6	34.9	31.6
10-3	72.8	942.3	434.2	79.7	1017.5	500.2	3.3	41.6	57.9	10.5	28.4	16.9
11-1	57.0	969.7	421.0	63.4	1013.2	498.1	1.3	14.7	45.9	17.9	74.9	17.5
11-2	72.1	668.1	504.3	78.1	701.9	609.9	2.8	11.8	64.0	14.3	44.9	22.3

11-3	35.6			39.2			0.8			8.4		
13-1	103.8	1648.6	1013.8	123.0	1687.1	1048.1	1.9	15.9	22.8	36.3	46.8	20.4
13-2	68.4	1240.3	1011.0	75.8	1276.7	1097.5	0.9	12.5	43.8	25.5	76.6	25.3
14-1	54.3	3172.6	473.4	60.1	3215.7	584.8	1.3	20.5	83.2	8.8	49.7	17.9
14-2	66.4	3159.6	633.9	74.6	3202.9	771.0	4.1	17.9	106.6	11.0	43.0	27.1
14-3	51.7	3649.2	347.6	56.7	3694.6	418.1	1.5	21.5	49.1	11.4	41.4	14.8
15-1	153.7	1486.2	7883.4	163.9	1507.3	7933.0	4.8	8.8	28.2	17.8	40.6	25.9
15-2	180.6	2053.7	4830.9	194.6	2083.6	4881.0	5.9	10.4	30.4	12.8	63.6	30.7
15-3	87.8	2500.0	2032.1	92.9	2528.6	2076.0	1.8	9.3	44.3	7.4	43.5	27.1
17-1	68.6	1323.2	3011.9	82.8	1416.6	3672.8	1.4	44.3	400.9	15.0	59.2	579.8
17-2	67.7	1390.3	3111.5	78.2	1511.5	3777.7	2.8	53.0	533.8	11.2	75.3	263.9
17-3	76.1	1578.9	4121.3	85.1	1695.4	5078.2	2.3	59.2	616.1	6.7	115.4	260.3
19-1	81.5	4430.7		91.4	5287.5		2.5	1292.6		15.6	102.7	
19-2	88.2	4908.5		94.2	5923.5		2.3	1581.8		12.6	91.7	
19-3	83.8	4714.7		92.5	5997.2		3.1	1341.6		8.1	109.7	
20-1	44.6	1246.8	1519.6	48.8	1389.6	1934.1	1.5	151.5	514.6	8.4	32.6	53.6
20-2	72.6	1165.1	1151.3	81.5	1283.5	1467.5	3.5	108.1	332.0	12.4	42.6	47.0
20-3	48.7	1356.0	1200.4	55.9	1470.8	1507.2	1.3	85.5	346.7	12.0	30.8	40.1
22-1	48.8	236.0	171.5	53.5	251.2	195.2	1.6	8.0	16.6	11.8	20.3	12.1
22-2	57.3	250.0	203.5	69.0	266.4	232.1	1.9	6.6	21.6	13.8	22.7	15.7
22-3	50.0	160.9	243.6	56.8	172.7	297.5	1.1	4.5	14.2	10.7	14.7	70.6
23-1	38.0	2215.0	349.2	41.7	2263.7	363.3	1.2	13.3	3.2	7.7	71.2	15.0
23-2	35.5	1510.7	232.4	40.6	1563.4	245.9	1.2	11.6	3.0	8.1	51.6	15.9
23-3	37.7	3008.8	272.3	41.8	3273.0	288.4	0.9	11.2	2.5	11.1	85.0	19.2
24-1	51.3	2404.2	654.6	60.1	2450.4	723.7	1.1	10.4	20.5	14.7	34.7	10.1
24-2	71.9	2348.3	740.1	77.2	2391.1	835.9	1.5	11.4	32.4	14.6	61.1	25.6
24-3	67.6		3038.6	75.6		3141.8	1.4		33.4	25.3		41.3

25-1	121.1	2235.7	290.8	132.4	2251.9	304.3	4.9	16.5	7.2	10.9	60.2	10.1
25-2	131.0	3296.0	700.1	140.9	3322.9	714.4	5.5	22.1	34.3	16.4	165.7	24.5
25-3	58.9	2830.4	759.6	68.5	2845.9	771.4	2.7	33.9	68.7	8.0	110.2	19.1
26-1	74.7	1693.4	579.9	80.6	1738.5	709.5	2.4	50.8	73.1	12.7	70.8	25.4
26-2	92.8	1206.1	2923.1	98.7	1237.2	3049.7	2.7	43.8	58.7	14.0	77.0	22.9
26-3	101.7	1265.7	1516.3	105.0	1303.5	1683.0	1.9	42.8	62.4	14.2	107.7	27.6
27-1	81.5	1535.2	1106.0	88.0	1599.7	1288.1	2.6	64.4	199.0	12.8	157.0	37.4
27-2	216.3	3538.2	5024.1	226.4	3593.3	5292.0	1.7	55.5	304.8	57.3	632.9	55.5
27-3	98.1	4428.5	962.0	104.1	4510.7	1254.1	2.9	70.1	199.2	13.6	308.4	46.7
28-2	146.4	833.1	1916.4	156.7	912.2	2575.0	4.9	48.6	428.6	14.4	36.1	58.0
28-3	363.3	1074.3	2398.3	458.7	1191.3	3184.2	2.0	86.5	593.8	205.5	121.3	74.1
30-1	148.4	1634.8	9010.9	162.9	1683.1	9047.6	4.5	21.6	20.2	20.0	69.7	20.2
30-2	120.9	2765.7	7431.4	129.9	2850.8	7465.6	4.8	21.6	26.6	11.0	39.8	18.0
30-3	48.8	2187.6	3455.1	54.3	2252.0	3492.7	1.7	22.8	27.9	11.1	66.3	18.2
32-1	119.0	2866.7	7781.4	127.9	2966.6	8366.2	3.7	103.3	392.3	9.3	90.5	262.6
32-2	110.1	4805.9	29418.7	118.0	4936.4	30074.7	3.9	118.2	552.9	20.7	55.7	92.7
32-3	111.8	2293.4	704.5	120.4	2389.6	946.7	3.4	15.0	75.9	19.5	316.6	53.7
33-1	105.3	1187.0	701.7	119.6	1222.2	909.2	4.0	15.5	72.2	19.0	65.7	21.5
33-2		1376.7	826.8		1408.6	1051.3		16.9	92.1		56.8	21.6
33-3	52.9	2299.5	1299.9	61.2	2318.7	1511.4	1.7	8.9	159.4	14.1	46.5	61.0
35-1	55.2	3502.6	2094.5	71.3	3531.2	2602.6	1.7	11.1	290.9	14.7	90.2	50.1
35-2	72.3	1821.1	2796.5	86.7	1853.3	3171.3	2.2	12.3	264.3	25.1	35.1	48.7
35-3	53.1	962.4	1603.4	56.6	1004.8	1879.0	1.0	30.3	147.0	12.7	64.1	46.5
36-1	38.5	891.6	3086.6	42.5	937.6	3420.9	1.3	30.6	197.1	6.7	90.3	46.2
36-2	52.9	1983.9	3025.0	60.8	2034.7	3359.5	2.2	31.9	179.9	10.9	66.8	42.9
36-3	102.6	3170.4	8384.1	110.2	3618.8	10251.4	3.0	54.5	212.6	12.0	61.8	47.3
37-1	36.2	3900.2	6840.1	40.9	4587.7	8721.2	0.7	96.9	320.3	7.0	82.0	263.2

37-2	157.8	3416.9	863.3	191.0	3467.1	1005.9	1.2	13.6	101.8	86.9	46.9	109.6
38-1	83.2	1046.6	644.1	110.5	1087.5	803.9	2.6	16.3	106.7	22.0	36.4	25.6
38-2	38.4	3591.0	423.8	42.8	3635.6	517.0	1.0	12.4	75.1	9.3	137.5	35.4
38-3	126.9	2357.1	10886.0	137.1	2533.4	12979.9	4.7	78.2	769.0	15.7	106.2	121.1
39-1	112.0	1926.2	8804.4	123.0	2029.5	11766.4	5.3	51.1	816.9	11.5	160.3	136.5
39-2	69.8	2536.0	20941.5	77.0	2770.7	23703.7	2.1	98.9	844.5	16.0	135.1	152.5
39-3	119.4	649.7	648.7	128.8	671.3	829.5	4.8	9.2	92.5	12.4	28.2	68.6
40-1	115.7	689.4	755.3	125.1	718.7	963.6	4.5	12.1	84.2	14.8	79.4	48.1
40-2	45.9	684.3	699.7	52.9	714.8	861.3	1.3	11.0	61.2	8.4	23.9	66.2
40-3	50.6	2390.6	1669.9	60.2	2545.2	1936.3	1.5	78.1	206.6	9.1	195.6	65.9
41-1	79.5	3259.3	1804.0	86.7	3376.4	2119.3	1.4	74.8	234.7	17.3	198.7	51.1
41-2	62.5	4209.8	2264.9	65.7	4312.0	2574.9	1.6	65.1	231.8	14.1	208.0	84.9
41-3	71.1	1128.7	576.9	78.6	1180.3	750.5	2.4	35.2	139.1	11.7	47.7	42.5
43-1	46.0	854.2	1205.8	50.8	914.9	1472.3	1.7	35.9	152.2	8.2	37.4	43.2
43-2	36.8	865.2	524.3	41.3	924.7	626.2	1.0	31.7	66.3	7.5	89.8	23.5
43-3	121.4	1174.6	1202.3	128.7	1290.4	1641.8	3.5	44.8	163.0	18.3	40.7	33.0
45-1	94.0	1436.8	1518.0	101.6	1584.5	2054.3	3.8	50.5	222.8	8.0	61.4	32.1
45-2	45.4	1535.8	1365.1	50.2	1656.1	1805.6	1.0	44.9	157.1	9.9	47.0	37.6
45-3	83.6	1019.2		90.9	1051.8		1.9	32.9		19.7	67.5	
46-1	66.3	1096.9	1257.2	73.0	1125.5	1385.8	1.7	58.5	447.5	13.7	47.7	56.9
46-2	65.8	991.2	2843.1	70.3	1074.3	3474.5	3.3	87.9	1094.0	12.4	44.3	113.0
46-3	137.2	2431.0	918.1	162.8	2457.7	999.7	1.4	6.3	10.8	74.3	145.8	135.6
48-1	59.9	1736.5	1246.3	67.4	1763.5	1322.7	1.8	7.2	15.1	10.7	117.6	51.1
48-2	50.5	1754.0	779.7	56.6	1783.9	824.2	0.9	6.0	17.0	13.3	37.8	182.4
48-3	50.5	927.6	526.3	56.9	965.5	685.6	1.0	10.2	50.2	16.9	152.5	80.1
49-1	66.3	436.3	444.7	74.2	462.1	553.2	2.8	9.5	33.9	12.3	52.5	23.5
49-2	30.4	573.4	447.9	34.6	598.9	555.4	0.8	7.2	29.4	5.4	49.0	18.3

49-3	52.2	2374.3	499.4	60.1	2402.2	526.4	1.5	16.2	14.2	7.7	73.2	53.4
50-1	60.3	3997.9	580.3	68.6	4031.5	627.5	1.8	18.7	29.0	13.5	79.9	45.9
50-2	53.8	2067.4	1125.9	63.6	2099.4	1167.4	2.1	20.6	32.6	7.7	154.6	74.8
50-3	43.6	1673.7	394.8	50.3	1697.6	472.6	1.3	8.2	65.0	10.1	38.9	50.0
51-1	74.3		470.5	84.8		568.0	2.3		76.6	14.9		30.5
51-2	45.0	1819.7	532.1	52.6	1840.1	658.1	1.1	10.9	122.4	10.9	32.6	36.0
MEAN	82.0	1922.4	2393.8	91.3	2025.1	2724.1	2.4	76.1	183.2	17.4	83.4	60.4
MEDIAN	70.7	1606.9	1125.9	78.1	1685.1	1288.1	1.9	23.0	84.2	12.7	63.8	42.9

14 Appendix G: Microenvironment Correlation

Table 14-1: Summary of correlation results between microenvironments

HOUSE_DAY	O-SUM81	I-SUM81	G-SUM81	O-TVOC	I-TVOC	G-TVOC	O-BTEX	I-BTEX	G-BTEX	O-SUM15CEPA	I-SUM15CEPA	G-SUM15CEPA
02-1	108.4	353.2	513.3	118.9	370.2	555.2	4.6	14.3	61.4	16.2	25.5	15.7
02-2	136.6	559.9	567.2	146.3	578.8	615.1	6.1	23.2	100.4	17.0	40.1	23.0
02-3	77.6	589.5	376.0	86.8	604.9	413.4	1.4	17.4	77.0	22.6	28.9	21.3
03-1	42.3	379.8	1815.5	46.5	418.2	2278.7	1.1	31.4	501.6	8.4	24.1	63.6
03-2	87.5	402.0	1843.8	99.2	457.0	2230.3	3.6	45.5	425.9	31.5	23.5	67.7
03-3	42.6	319.9	2038.8	48.4	357.9	2503.1	1.2	36.1	554.0	9.0	20.3	74.6
06-1	147.8	4093.8	2238.6	152.6	4180.8	2684.7	3.2	40.6	178.7	21.5	117.6	43.4
06-2	162.8	3273.4	2185.5	173.6	3382.4	2861.2	5.5	59.3	265.1	10.5	147.0	53.6
06-3	50.8	4111.6	2656.0	57.8	4271.1	3425.4	1.9	69.2	319.6	7.8	132.7	70.2
08-1	62.0	ND	470.0	67.5	ND	543.6	0.9	ND	42.5	21.6	ND	24.1
08-2	74.3	914.8	510.7	83.2	991.9	600.5	2.0	7.7	55.3	23.1	74.2	29.7
08-3	47.2	835.6	488.5	57.4	927.5	578.4	1.9	8.9	62.6	10.9	108.4	44.4
10-1	110.8	1149.5	ND	118.2	1214.3	ND	1.5	24.0	ND	36.7	68.8	ND
10-2	70.7	1280.4	3542.3	76.1	1351.2	3896.4	1.7	38.1	220.1	19.6	34.9	52.0
10-3	72.8	942.3	2633.2	79.7	1017.5	2985.8	3.3	41.6	184.9	10.5	28.4	31.6
11-1	57.0	969.7	434.2	63.4	1013.2	500.2	1.3	14.7	57.9	17.9	74.9	16.9
11-2	72.1	668.1	421.0	78.1	701.9	498.1	2.8	11.8	45.9	14.3	44.9	17.5

11-3	35.6	ND	504.3	39.2	ND	609.9	0.8	ND	64.0	8.4	ND	22.3
13-1	103.8	1648.6	1013.8	123.0	1687.1	1048.1	1.9	15.9	22.8	36.3	46.8	20.4
13-2	68.4	1240.3	1011.0	75.8	1276.7	1097.5	0.9	12.5	43.8	25.5	76.6	25.3
14-1	54.3	3172.6	473.4	60.1	3215.7	584.8	1.3	20.5	83.2	8.8	49.7	17.9
14-2	66.4	3159.6	633.9	74.6	3202.9	771.0	4.1	17.9	106.6	11.0	43.0	27.1
14-3	51.7	3649.2	347.6	56.7	3694.6	418.1	1.5	21.5	49.1	11.4	41.4	14.8
15-1	153.7	1486.2	7883.4	163.9	1507.3	7933.0	4.8	8.8	28.2	17.8	40.6	25.9
15-2	180.6	2053.7	4830.9	194.6	2083.6	4881.0	5.9	10.4	30.4	12.8	63.6	30.7
15-3	87.8	2500.0	2032.1	92.9	2528.6	2076.0	1.8	9.3	44.3	7.4	43.5	27.1
17-1	68.6	1323.2	3011.9	82.8	1416.6	3672.8	1.4	44.3	400.9	15.0	59.2	579.8
17-2	67.7	1390.3	3111.5	78.2	1511.5	3777.7	2.8	53.0	533.8	11.2	75.3	263.9
17-3	76.1	1578.9	4121.3	85.1	1695.4	5078.2	2.3	59.2	616.1	6.7	115.4	260.3
19-1	81.5	4430.7	ND	91.4	5287.5	ND	2.5	1292.6	ND	15.6	102.7	ND
19-2	88.2	4908.5	ND	94.2	5923.5	ND	2.3	1581.8	ND	12.6	91.7	ND
19-3	83.8	4714.7	ND	92.5	5997.2	ND	3.1	1341.6	ND	8.1	109.7	ND
20-1	44.6	1246.8	1519.6	48.8	1389.6	1934.1	1.5	151.5	514.6	8.4	32.6	53.6
20-2	72.6	1165.1	1151.3	81.5	1283.5	1467.5	3.5	108.1	332.0	12.4	42.6	47.0
20-3	48.7	1356.0	1200.4	55.9	1470.8	1507.2	1.3	85.5	346.7	12.0	30.8	40.1
22-1	48.8	236.0	171.5	53.5	251.2	195.2	1.6	8.0	16.6	11.8	20.3	12.1
22-2	57.3	250.0	203.5	69.0	266.4	232.1	1.9	6.6	21.6	13.8	22.7	15.7
22-3	50.0	160.9	243.6	56.8	172.7	297.5	1.1	4.5	14.2	10.7	14.7	70.6
23-1	38.0	2215.0	349.2	41.7	2263.7	363.3	1.2	13.3	3.2	7.7	71.2	15.0
23-2	35.5	1510.7	232.4	40.6	1563.4	245.9	1.2	11.6	3.0	8.1	51.6	15.9
23-3	37.7	3008.8	272.3	41.8	3273.0	288.4	0.9	11.2	2.5	11.1	85.0	19.2
24-1	51.3	2404.2	654.6	60.1	2450.4	723.7	1.1	10.4	20.5	14.7	34.7	10.1
24-2	71.9	2348.3	740.1	77.2	2391.1	835.9	1.5	11.4	32.4	14.6	61.1	25.6
24-3	67.6	ND	3038.6	75.6	ND	3141.8	1.4	ND	33.4	25.3	ND	41.3

25-1	121.1	2235.7	290.8	132.4	2251.9	304.3	4.9	16.5	7.2	10.9	60.2	10.1
25-2	131.0	3296.0	700.1	140.9	3322.9	714.4	5.5	22.1	34.3	16.4	165.7	24.5
25-3	58.9	2830.4	759.6	68.5	2845.9	771.4	2.7	33.9	68.7	8.0	110.2	19.1
26-1	74.7	1693.4	579.9	80.6	1738.5	709.5	2.4	50.8	73.1	12.7	70.8	25.4
26-2	92.8	1206.1	2923.1	98.7	1237.2	3049.7	2.7	43.8	58.7	14.0	77.0	22.9
26-3	101.7	1265.7	1516.3	105.0	1303.5	1683.0	1.9	42.8	62.4	14.2	107.7	27.6
27-1	81.5	1535.2	1106.0	88.0	1599.7	1288.1	2.6	64.4	199.0	12.8	157.0	37.4
27-2	216.3	3538.2	5024.1	226.4	3593.3	5292.0	1.7	55.5	304.8	57.3	632.9	55.5
27-3	98.1	4428.5	962.0	104.1	4510.7	1254.1	2.9	70.1	199.2	13.6	308.4	46.7
28-2	146.4	833.1	1916.4	156.7	912.2	2575.0	4.9	48.6	428.6	14.4	36.1	58.0
28-3	363.3	1074.3	2398.3	458.7	1191.3	3184.2	2.0	86.5	593.8	205.5	121.3	74.1
30-1	148.4	1634.8	9010.9	162.9	1683.1	9047.6	4.5	21.6	20.2	20.0	69.7	20.2
30-2	120.9	2765.7	7431.4	129.9	2850.8	7465.6	4.8	21.6	26.6	11.0	39.8	18.0
30-3	48.8	2187.6	3455.1	54.3	2252.0	3492.7	1.7	22.8	27.9	11.1	66.3	18.2
32-1	119.0	ND	7781.4	127.9	ND	8366.2	3.7	ND	392.3	9.3	ND	262.6
32-2	110.1	ND	ND	118.0	ND	ND	3.9	ND	ND	20.7	ND	ND
32-3	ND	ND	29418.7	ND	ND	30074.7	ND	ND	552.9	ND	ND	92.7
33-1	111.8	2293.4	704.5	120.4	2389.6	946.7	3.4	15.0	75.9	19.5	316.6	53.7
33-2	105.3	1187.0	701.7	119.6	1222.2	909.2	4.0	15.5	72.2	19.0	65.7	21.5
33-3	ND	1376.7	826.8	ND	1408.6	1051.3	ND	16.9	92.1	ND	56.8	21.6
35-1	52.9	2299.5	1299.9	61.2	2318.7	1511.4	1.7	8.9	159.4	14.1	46.5	61.0
35-2	55.2	3502.6	2094.5	71.3	3531.2	2602.6	1.7	11.1	290.9	14.7	90.2	50.1
35-3	72.3	1821.1	2796.5	86.7	1853.3	3171.3	2.2	12.3	264.3	25.1	35.1	48.7
36-1	53.1	962.4	1603.4	56.6	1004.8	1879.0	1.0	30.3	147.0	12.7	64.1	46.5
36-2	38.5	891.6	3086.6	42.5	937.6	3420.9	1.3	30.6	197.1	6.7	90.3	46.2
36-3	52.9	1983.9	3025.0	60.8	2034.7	3359.5	2.2	31.9	179.9	10.9	66.8	42.9
37-1	102.6	3170.4	8384.1	110.2	3618.8	10251.4	3.0	54.5	212.6	12.0	61.8	47.3

37-2	36.2	3900.2	6840.1	40.9	4587.7	8721.2	0.7	96.9	320.3	7.0	82.0	263.2
38-1	157.8	3416.9	863.3	191.0	3467.1	1005.9	1.2	13.6	101.8	86.9	46.9	109.6
38-2	83.2	1046.6	644.1	110.5	1087.5	803.9	2.6	16.3	106.7	22.0	36.4	25.6
38-3	38.4	3591.0	423.8	42.8	3635.6	517.0	1.0	12.4	75.1	9.3	137.5	35.4
39-1	126.9	2357.1	10886.0	137.1	2533.4	12979.9	4.7	78.2	769.0	15.7	106.2	121.1
39-2	112.0	1926.2	8804.4	123.0	2029.5	11766.4	5.3	51.1	816.9	11.5	160.3	136.5
39-3	69.8	2536.0	20941.5	77.0	2770.7	23703.7	2.1	98.9	844.5	16.0	135.1	152.5
40-1	119.4	649.7	648.7	128.8	671.3	829.5	4.8	9.2	92.5	12.4	28.2	68.6
40-2	115.7	689.4	755.3	125.1	718.7	963.6	4.5	12.1	84.2	14.8	79.4	48.1
40-3	45.9	684.3	699.7	52.9	714.8	861.3	1.3	11.0	61.2	8.4	23.9	66.2
41-1	50.6	2390.6	1669.9	60.2	2545.2	1936.3	1.5	78.1	206.6	9.1	195.6	65.9
41-2	79.5	3259.3	1804.0	86.7	3376.4	2119.3	1.4	74.8	234.7	17.3	198.7	51.1
41-3	62.5	4209.8	2264.9	65.7	4312.0	2574.9	1.6	65.1	231.8	14.1	208.0	84.9
43-1	71.1	1128.7	576.9	78.6	1180.3	750.5	2.4	35.2	139.1	11.7	47.7	42.5
43-2	45.9	854.2	1205.8	50.8	914.9	1472.3	1.7	35.9	152.2	8.2	37.4	43.2
43-3	36.8	865.2	524.3	41.3	924.7	626.2	1.0	31.7	66.3	7.5	89.8	23.5
45-1	121.4	1174.6	1202.3	128.7	1290.4	1641.8	3.5	44.8	163.0	18.3	40.7	33.0
45-2	94.0	1436.8	1518.0	101.6	1584.5	2054.3	3.8	50.5	222.8	8.0	61.4	32.1
45-3	45.4	1535.8	1365.1	50.2	1656.1	1805.6	1.0	44.9	157.1	9.9	47.0	37.6
46-1	83.6	1019.2	ND	90.9	1051.8	ND	1.9	32.9	ND	19.7	67.5	ND
46-2	66.3	1096.9	1257.2	73.0	1125.5	1385.8	1.7	58.5	447.5	13.7	47.7	56.9
46-3	65.8	991.2	2843.1	70.3	1074.3	3474.5	3.3	87.9	1094.0	12.4	44.3	113.0
48-1	137.2	2431.0	918.1	162.8	2457.7	999.7	1.4	6.3	10.8	74.3	145.8	135.6
48-2	59.9	1736.5	1246.3	67.4	1763.5	1322.7	1.8	7.2	15.1	10.7	117.6	51.1
48-3	50.5	1754.0	779.7	56.6	1783.9	824.2	0.9	6.0	17.0	13.3	37.8	182.4
49-1	50.5	927.6	526.3	56.9	965.5	685.6	1.0	10.2	50.2	16.9	152.5	80.1
49-2	66.3	436.3	444.7	74.2	462.1	553.2	2.8	9.5	33.9	12.3	52.5	23.5

49-3	30.4	573.4	447.9	34.6	598.9	555.4	0.8	7.2	29.4	5.4	49.0	18.3
50-1	52.2	2374.3	499.4	60.1	2402.2	526.4	1.5	16.2	14.2	7.7	73.2	53.4
50-2	60.3	3997.9	580.3	68.6	4031.5	627.5	1.8	18.7	29.0	13.5	79.9	45.9
50-3	53.8	2067.4	1125.9	63.6	2099.4	1167.4	2.1	20.6	32.6	7.7	154.6	74.8
51-1	43.6	1673.7	394.8	50.3	1697.6	472.6	1.3	8.2	65.0	10.1	38.9	50.0
51-2	74.3	ND	470.5	84.8	ND	568.0	2.3	ND	76.6	14.9	ND	30.5
51-3	45.0	1819.7	ND	52.6	1840.1	ND	1.1	10.9	ND	10.9	32.6	ND
MEDIAN	70.7	1557.4	1138.6	78.1	1669.6	1305.4	1.9	22.4	83.7	12.7	63.8	43.1

15 Appendix H: VOC ID Data Dictionary

Table 15-1: Summary of Compounds and Assigned modelling ID

ID	Compound	MW (g/mol)			
S001	Acetylene	26.04	S015	1_3_Butadiene	54.09
S002	Ethylene	28.05	S016	Acrolein (2_Propenal)	56.06
S003	Ethane	30.07	S017	1_Butene/2_Methylpropene	56.11
S004	Methanol	32.04	S018	c_2_Butene	56.11
S005	Propyne	40.06	S019	t_2_Butene	56.11
S006	Acetonitrile	41.05	S020	Acetone	58.08
S007	Propene	42.08	S021	Propionaldehyde	58.08
S008	Acetaldehyde	44.05	S022	Propylene Oxide	58.08
S009	Ethylene oxide	44.05	S023	Butane	58.12
S010	Propane	44.10	S024	Isobutane (2_Methylpropane)	58.12
S011	Ethanol	46.07	S025	Isopropyl Alcohol	60.10
S012	Chloromethane	50.49	S026	Propyl alcohol (1_Propanol)	60.10
S013	Acrylonitrile (2_Propennitrile)	53.06	S027	Vinylchloride (Chloroethene)	62.50
S014	1_Butyne	54.09	S028	Chloroethane	64.51
			S029	Cyclopentene	68.11

S030	Isoprene (2_Methyl_1_3_Butadiene)	68.12
S031	MVK	70.09
S032	Cyclopentane	70.10
S033	1_Pentene	70.13
S034	c_2_Pentene	70.13
S035	t_2_Pentene	70.13
S036	2_Methyl_1_Butene	70.13
S037	2_Methyl_2_Butene	70.13
S038	3_Methyl_1_Butene	70.13
S039	2_Butenal (Crotonaldehyde)	72.11
S040	2_Methyl_Propanal	72.11
S041	Butylaldehyde (Butanal)	72.11
S042	MEK (2-Butanone)	72.11
S043	2_2_Dimethylpropane	72.15
S044	2_Methylbutane	72.15
S045	Pentane	72.15
S046	Methyl Acetate	74.08
S047	1_Butanol (Butyl alcohol)	74.12

S048	2_Butanol	74.12
S049	Isobutylalcohol	74.12
S050	Carbon Disulfide	76.14
S051	Benzene	78.11
S052	2_Methylfuran	82.10
S053	3_Methylfuran	82.10
S054	1_Methylcyclopentene	82.14
S055	Cyclohexene	82.14
S056	Cyclopentanone	84.12
S057	2_Ethyl_1_Butene	84.16
S058	3_Methyl_1_Pentene	84.16
S059	4_Methyl_1_Pentene	84.16
S060	c_2_Hexene	84.16
S061	c_3_Methyl_2_Pentene	84.16
S062	c_4_Methyl_2_Pentene	84.16
S063	Cyclohexane	84.16
S064	Methylcyclopentane	84.16
S065	t_2_Hexene	84.16

S066	t_3_Methyl_2_Pentene	84.16
S067	t_4_Methyl_2_Pentene	84.16
S068	1_Hexene/ 2_Methyl_1_Pentene	84.16
S069	Dichloromethane	84.93
S070	2_Methylbutanal (Isovaleraldehyde)	86.13
S071	2_Pentanone	86.13
S072	Pentanal	86.13
S073	2_2_Dimethylbutane	86.17
S074	2_3_Dimethylbutane	86.17
S075	2_Methylpentane	86.18
S076	3_Methylpentane	86.18
S077	Hexane	86.18
S078	Freon 22 (Chlorodifluoromethane)	86.47
S079	Ethylacetate	88.11
S080	Methyl_t_Butyl Ether (MTBE)	88.15
S081	3_Methyl_1_Butanol	88.15

S082	MAC (2_Methyl_2_propenal)	90.55
S083	Toluene	92.14
S084	Bromomethane	94.94
S085	c_1_2_Dichloroethene	96.94
S086	t_1_2_Dichloroethene	96.94
S087	1_1_Dichloroethene	96.95
S088	Cyclohexanone	98.15
S089	1_Methylcyclohexene	98.19
S090	1_Heptene	98.19
S091	c_2_Heptene	98.19
S092	c_3_Heptene	98.19
S093	Methylcyclohexane	98.19
S094	t_2_Heptene	98.19
S095	t_3_Heptene	98.19
S096	1_1_Dichloroethane	98.96
S097	1_2_Dichloroethane	98.96
S098	Hexanal	100.16
S099	MIBK	100.16

S100	2_Hexanone	100.16
S101	2_2_3_Trimethylbutane	100.20
S102	2_2_Dimethylpentane	100.20
S103	2_3_Dimethylpentane	100.20
S104	2_Methylhexane	100.20
S105	3_Methylhexane	100.20
S106	Heptane	100.20
S107	2_4_Dimethylpentane	100.20
S108	Freon 134A	102.03
S109	Isopropylacetate	102.13
S110	Styrene	104.15
S111	Benzaldehyde	106.12
S112	Ethylbenzene	106.17
S113	m_p_Xylene	106.17
S114	o_Xylene	106.17
S115	Ethylbromide	108.97
S116	c_1_3_Dichloropropene	110.97
S117	T_1_3_Dichloropropene	110.97

S118	c-1,2-Dimethylcyclohexane	112.21
S119	c-1,3-Dimethylcyclohexane	112.21
S120	c-1,4/ t-1,3-Dimethylcyclohexane	112.21
S121	t_1_2_Dimethylcyclohexane	112.21
S122	t_1_4_Dimethylcyclohexane	112.21
S123	t_2_Octene	112.21
S124	1_Octene	112.24
S125	Chlorobenzene	112.56
S126	1_2_Dichloropropane	112.99
S127	2_Heptanone	114.19
S128	2_2_4_Trimethylpentane	114.22
S129	2_3_4_Trimethylpentane	114.22
S130	2_2_Dimethylhexane	114.23
S131	2_4_Dimethylhexane	114.23
S132	2_5_Dimethylhexane	114.23
S133	2_Methylheptane	114.23
S134	3_Methylheptane	114.23
S135	4_Methylheptane	114.23

S136	Octane	114.23
S137	Butylacetate	116.16
S138	Isobutylacetate	116.16
S139	Indan (2_3_Dihydroindene)	118.18
S140	Chloroform	119.38
S141	1_2_3_Trimethylbenzene	120.19
S142	1_2_4_Trimethylbenzene	120.19
S143	1_3_5_Trimethylbenzene	120.19
S144	2_Ethyltoluene	120.19
S145	3_Ethyltoluene	120.19
S146	4_Ethyltoluene	120.19
S147	iso_Propylbenzene	120.19
S148	n_Propylbenzene	120.19
S149	Freon 12 (Dichlorodifluoromethane)	120.91
S150	1_Nonene	126.24
S151	Benzyl Chloride	126.58
S152	1_4_Dichlorobutane	127.01
S153	2_2_5_Trimethylhexane	128.16

S154	Naphthalene	128.17
S155	Nonane	128.26
S156	Trichloroethene	131.39
S157	1_1_1_Trichloroethane	133.40
S158	1_1_2_Trichloroethane	133.40
S159	1,2,4,5-Tetramethylbenzene	134.22
S160	1_2_Diethylbenzene	134.22
S161	1_3_Diethylbenzene	134.22
S162	1_4_Diethylbenzene	134.22
S163	iso_Butylbenzene	134.22
S164	n_Butylbenzene	134.22
S165	p_Cymene (1_Methyl_4_Isopropylbenzene)	134.22
S166	sec_Butylbenzene	134.22
S167	tert_Butylbenzene	134.22
S168	a_Pinene	136.23
S169	b_Pinene	136.23
S170	Limonene	136.23

S171	Camphene	136.24
S172	Freon 11 (Trichlorofluoromethane)	137.37
S173	1-Decene	140.27
S174	Nonanal	142.24
S175	3_6_Dimethyloctane	142.28
S176	Decane	142.29
S177	1_2_Dichlorobenzene	147.01
S178	1_3_Dichlorobenzene	147.01
S179	1_4_Dichlorobenzene	147.01
S180	Carbon tetrachloride	153.82
S181	1-Undecene	154.29
S182	Decanal	156.20
S183	Undecane	156.31
S184	Hexylbenzene	162.27
S185	Bromodichloromethane	163.83
S186	Tetrachloroethene	165.83

S187	1_1_2_2_Tetrachloroethane	167.85
S188	Dodecane	170.33
S189	Freon 114 (1,2-Dichlorotetrafluoroethane)	170.92
S190	Dibromomethane	173.83
S191	1_2_4_Trichlorobenzene	181.45
S192	Tridecane	184.36
S193	Freon 113 (1,1,2-Trichlorotrifluoroethane)	187.38
S194	1_2_Dibromoethane	187.86
S195	Bromotrichloromethane	198.27
S196	Tetradecane	198.39
S197	Dibromochloromethane	208.28
S198	Pentadecane	212.41
S199	Hexadecane	226.44
S200	Bromoform	252.73
S201	Hexachlorobutadiene	260.76