Wood Buffalo Environmental Association
Human Exposure Monitoring Program

Part I - Methods Report
Part II - 2005 Monitoring Year Results

February 2007

The Wood Buffalo Environmental Association's Human Exposure Monitoring Program is an extension and continuation of the original Alberta Oil Sands Community Exposure and Health Effects Assessment Program which was completed in 2000 by the Health Surveillance Branch of Alberta Health and Wellness.

Since the original program, other Community Exposure and Health Effects Assessment Programs (CEHEAPs) have been completed:

The Wabamun and Area Community Exposure and Health Effects Assessment Program: Final Report, 2006
The Fort Saskatchewan and Area Community Exposure and Health Effects Assessment Program: Final Report, 2003
The Grande Prairie and Area Community Exposure and Health Effects Assessment Program: Final Report, 2002
The Alberta Oil Sands Community Exposure and Health Effects Assessment Program: Summary Report, 2000
The Alberta Oil Sands Community Exposure and Health Effects Assessment Program: Technical Report, 2000
The Alberta Oil Sands Community Exposure and Health Effects Assessment Program: Methods Report, 2000
The Alberta Oil Sands Community Exposure and Health Effects Assessment Program: Pilot Study Report, 1997

Disclaimer: The organizations represented on the Human Exposure Monitoring Program Steering Committee are recognized for their contributions and support of the WBEA Human Exposure Monitoring Program. Although the program is directed by a multi-stakeholder consultation process, this scientific report may not reflect the views of these organizations. Any inquiries regarding the methods utilized in compiling and analyzing information and samples collected from the participants should be directed towards the Public Health Surveillance and Environmental Health Branch, Alberta Health and Wellness.

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This report provides the results of a human exposure and health effects assessment conducted within the Wood Buffalo Environmental Association during the fall of 2005. The assessment used a protocol developed in Alberta to assess personal exposure and the potential health impact of airborne contaminants.

The list of organizations below is recognized for their continued support and assistance of the ongoing monitoring program. It should be acknowledged that representatives for some of these organizations have changed over time and that the contributions of these individuals were valued and appreciated.

Wood Buffalo Environmental Association – Human Exposure Monitoring Committee (WBEA-HEMC)

Science Advisory Team of Alberta Health & Wellness

WBEA HEMC and the Science Team would like to thank the efforts of the project co-ordinator and field staff that was instrumental in the deployment of the 2005 Human Exposure Monitoring Program (HEMP).

Finally, the Science Team and WBEA HEMC would also like to gratefully acknowledge the contributions made by all volunteers in the communities of Fort Chipewyan and Fort McMurray whose participation in this program was critical to its success.

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Executive Summary

Objectives

This report summarizes the methodology and results of the first year of an ongoing community exposure and health effects assessment program undertaken in the Wood Buffalo region of northeastern Alberta. While the Wood Buffalo region enjoys good air quality most of the time, increased industrial activity and subsequent population growth has raised people's awareness about air quality and quality of life in the region.

In response to this, the Wood Buffalo Environmental Association (WBEA) has established a Human Exposure Monitoring Program (HEMP) in the Wood Buffalo region. Supported by scientific and technical assistance from Alberta Health and Wellness, information about the background, design and the first year of monitoring results are presented in this report.

The purpose of the Program is to monitor levels of people's exposure to selected air pollutants over time and to gather better information on factors that contribute to these exposures. This can be accomplished by:

- Obtaining true information on amounts of air pollutants that people are exposed to, and how much is indoors and outdoors at their homes.
- Providing better information in order to allow people in the region to make informed decisions about the role of indoor and outdoor air pollution.
- Better understanding the relationships between amounts of air pollutants that people are exposed to and amounts indoors and outdoors. Also, improving our understanding about which factors affect personal exposure.
- Make recommendations on ways to reduce people's exposure that will have a real benefit in improving quality of life in Wood Buffalo Region.

Methods and Analysis

The data used for the analysis was collected over a 16 week period (January 10, 2005 to April 27, 2005), using volunteers from two communities, Fort McMurray and Fort Chipewyan. Data was evaluated and where applicable, additional comparisons were made to scientific literature, and to the previous community exposure and health effects assessment program deployed in the region (Alberta Oil Sands Community Exposure and health Effects Assessment Program, 2000). The program collected a variety of measures for each participant including personal, indoor, and outdoor levels of selected contaminants including (nitrogen dioxide, sulfur dioxide, ozone and a panel of volatile organic compounds). In addition, all participants in this ongoing program wore active monitors which collected particulate matter. Participants also completed a demographic and exposure survey and time activity diaries to characterize other potential exposures.

Significant Findings

In total 59 participants volunteered to provide a complete set of measurements for inclusion into this report. While this is one less than the required protocol, it does suggest that exposure to contaminants from air-borne sources may be of concern for residents in this area and there is sufficient community interest for this program.

The participation of these two communities provides an initial starting point or beginning of an ongoing human exposure monitoring program. Two subgroups were created, with 29 participants from the City of Fort McMurray and 30 from the town of Fort Chipewyan. For both sample groups, the majority of the participants were female which is common in these types of program. Fort McMurray participants in comparison to those from Fort Chipewyan had higher levels of income and education. The percentage of current smokers in each community was lower than the provincial average of 20%, with a slightly higher proportion of Fort Chipewyan participants being smokers. Finally, both sample groups spent the highest proportion of their day indoors at home and had lived in either community for five years or less.

Due to the small sample sizes taken from each community, it is difficult to draw firm conclusions as to how personal exposure to the following airborne contaminants is occurring. As HEMP progresses, it is expected that a clearer understanding of how and what influences personal exposure will become better defined.

Analysis of the individual measures of exposure for the 2005 monitoring year indicated:

- For both communities monitored in 2005, exposure to nitrogen dioxide (NO_2) was lower than existing guidelines.
    - While the levels of nitrogen dioxide were higher in Fort McMurray compared to the 2000 Alberta Oil Sands Community Exposure and Health Assessments Program, these increases are likely a result of increased population, industry and vehicle emissions within the community.
    - Levels of nitrogen dioxide were lower in Fort Chipewyan sample compared to Fort McMurray sample. Future monitoring in this project will provide indications of what levels of personal exposure in occurring in the community.

- Levels of sulfur dioxide (SO_2) measured in both communities were very low compared to existing guidelines.
    - The level of personal exposure to sulfur dioxide in the 2005 Fort McMurray participants is lower, although outdoor levels had increased. Again, this increased sulfur dioxide level is likely a reflection of an increased population and industrial activities.
    - In Fort Chipewyan, personal exposure levels to sulfur dioxide were the same as the Fort McMurray participants even though outdoor concentrations were lower. The reason for this same personal exposure may be determined over time with ongoing monitoring in this community.

- Personal and indoor levels of exposure to ozone (O_3) were very low with indoor and outdoor exposure levels lower than existing guidelines or reference values.
    - From the 2005 Fort McMurray participants, the level of personal and indoor exposure to ozone had decreased, with a slight increase in outdoor concentrations compared to 2000 results.
    - The levels of ozone concentrations were higher in Fort Chipewyan when compared to the Fort McMurray samples. However, as ozone is destroyed as it chemically reacts with other components in the air, the inherent inaccuracy of using outdoor concentrations as a reflection of personal exposure is identified.

- Indoor concentrations were the predominant factor affecting personal exposure to volatile organic compounds (VOCs). With the exception of benzene, many outdoor monitors did not detect VOCs in the outside or ambient air.
    - Three of the VOCs examined currently have ambient air quality objectives as determined by Alberta Environment. These three VOCs are benzene, ethylbenzene and toluene. It should be noted that all outdoor monitors were below their respective objectives.

- Outdoor $PM_{2.5}$ concentrations for both monitored communities were lower than current guidelines as well as the 2010 proposed Canadian wide standard.
    - Levels for the three sampler locations in Fort McMurray had decreased in comparison to the 2000 community health assessment and exposure program. In particular, outdoor levels of $PM_{2.5}$ do not seem to significantly impacting personal exposure. As the personal and indoor medians are not closely related, personal exposure appears to be influenced by other factors such as lifestyle choices (i.e. smoking) or occupation.

    - In Fort Chipewyan, the personal median concentration is higher then the Fort McMurray sample, this exposure appears to be strongly linked to indoor source or lifestyle activities (such as smoking). The Fort Chipewyan sample did have a slightly higher proportion of smokers which may have influenced this measurement. As the outdoor median concentration is low, an outdoor source(s) do not appear to be attributing to personal exposure in this sample population.

Recommendations

1. Continued implementation of the Human Exposure Monitoring Program

A primary purpose of the program is to attempt to determine the effects of exposure of airborne contaminants particularly the effect of outdoor or ambient levels on human health. As it is known that these exposures are low, the determination of these effects will have to be measured over the long term. In order to achieve this goal, HEMP must be continually deployed as per its prescribed schedule.

2. Amalgamation of participant data as HEMP progresses

To determine long term health effects, methods must be devised to amalgamate each community's data to determine trending and measure potential health effects. Achievement of this goal may also be partly accomplished by continuing to contact participants from previous years to determine how their personal exposure levels are changing over time.

3. Creation of a community focused education program about exposure pathways to airborne contaminants or pollutants.

As in the 2000 Alberta Oil Sands Community Exposure and Assessment Program, the highest exposure to the measured contaminants appears to be related to indoor sources (e.g. tobacco smoke, off gassing from consumer products or combustion sources). While all the measured levels were low, improving the public's knowledge and understanding about how and where airborne contaminants may be found or created could reduce exposure regardless of source (indoor or outdoor). In addition, reducing indoor or other related sources may also allow for a better measure of impact from outdoor sources.

Part I – Methods Report

1.0 Introduction

The Wood Buffalo Environmental Association (WBEA) is a non-profit, community-driven organization that operates modern environmental monitoring programs. WBEA monitors and reports information on air quality and environmental impacts in the Wood Buffalo Region located in northeastern Alberta.

Despite great success achieved by the oil sands industry in reducing air pollutant releases, air quality is recognized by people in the region as having potential affects to health and well-being. With this in mind, WBEA supported the establishment of a human exposure monitoring program. While many environmental monitoring programs in North America focus on monitoring air, water, land, and other parts of the environment, this program focuses on human's and their health.

Why "human exposure" monitoring? Over the past 25 years, scientific studies[1,2,3,4] have shown that exposure is a key link in understanding the role between the environment and health status (diseases) in a population. Exposure to air pollutants is only one of a number of factors that may cause diseases such as asthma.[5,6] The program can also provide people with an understanding of what factors are important with respect to air pollution exposure. This information is valuable for the public. It provides people with a basis to make informed decisions about air quality and how it relates to their health.

2.0 Background and Rationale

In general, exposure can be defined as any contact between a substance, biological agent or radiation with an individual or community. We are all exposed to low levels of contamination in the air we breathe, the food we water we drink, and the consumer products we use. Contaminants can interfere with the normal biological functions, causing effects range from subtle biochemical changes to clinical disease or even death. An exposure pathway describes how a contaminant or pollutant travels through the environment from its source to humans. An exposure pathway consists of five elements[7,8,9,10]:

- Source(s) of contamination;
- Environmental media;
- Point of exposure;
- A person or population; and
- Route of Exposure

The output of each element in the chain of events serves as input into the next. The lack of information on any one element thus impairs our ability to make accurate assessments of the associated population health risks. Environmental health surveillance is a tool that can be used to gather data and information on the health of people for the purpose of tracking and detecting trends and associations among a broad range of environmental and health related variables. The process consists of an on-going systematic collection, analysis and interpretation of the selected data on health outcomes, environmental quality parameters and population exposure. In addition, data on behavioural, lifestyle, social, economic and other confounding variables are considered.

The Human Exposure Monitoring Program (HEMP) was developed to obtain measures of exposure to a variety of contaminants across a continuum of exposure, including measure of contaminants in the environment and the quantity of contaminants to which an individual is exposed through these sources. In

particular, HEMP focuses on air borne contaminants, and what an individual has breathed in throughout their normal activities.

Indoor Air versus Outdoor Air

Outdoor air pollution can come many different sources including motor vehicles, industries, commercial businesses and even dust. Sources of indoor pollution include building materials, carpets, paint, fireplaces and any other consumer products that we use in our homes. While most people believe that exposure to outdoor air pollution can damage our health, few people realize that indoor air can be just as or even more harmful.[11] Studies by Alberta Health & Wellness,[12] Health Canada[13] and the US Environmental Protection Agency[14] have indicated that levels of many indoor air pollutants can be much higher than outdoor levels. Nevertheless, studies on urban populations have reported positive links between outdoor air pollutants and people's health.[15]

Even though Canadians spend a small amount of time outdoors (less than 12 percent on average)[16] this provides a starting point for gathering better information to understand the role that outdoor air pollution has in contributing to exposure in the Wood Buffalo region.

3.0 Program Objectives

The Wood Buffalo region enjoys air quality that is considered good most of the time. This can be readily confirmed in WBEA annual reports on air quality in the region.[17,18,19,20] At times, a combination of factors and natural events (e.g., forest fires) can create conditions that lead to poor air quality. However, occurrence of these conditions is infrequent compared to times in which air quality is good.

The ability to show that air pollutants are a cause of diseases in a population remains a challenge, particularly when exposures are small. Air pollution exposure is only one of a number of factors that may contribute to development of diseases. Because of this, HEMP emphasizes measurement of air pollution exposure. If exposures are high enough, these exposures may represent a link between air pollutants in the environment and diseases that occur in a population.

Measurement methods for air pollution – although well established in practice – are limited in being able to detect changes over short time periods. To overcome this, HEMP will periodically take measurements in a community over time – e.g. every couple of years. HEMP will also report findings of these measurements to the public.

This approach has the ability to accomplish the following objectives for WBEA:

- Obtain true information on amounts of air pollutants that people are exposed to, and how much is indoors and outdoors at their homes.
- Provide better information in order to allow people to make informed decisions about the role of indoor and outdoor air pollution.
- Expand the role that WBEA plays in providing thorough air quality information to people in communities throughout the Wood Buffalo region.

Scientists also benefit from having this type of information. Specifically, scientists can use this information to:

- Better understand relationships between amounts of air pollutants that people are exposed to and amounts indoors and outdoors.
- Better understand important factors affecting people's exposure.
- Make recommendations on ways to reduce people's exposure that will have a real benefit in improving quality of life in Wood Buffalo Region.

4.0 Program Method and Protocol

An initial community exposure study was undertaken in Fort McMurray in the late 1990s.[21] This study is referred to as the Alberta Oil Sands Community Exposure and Health Effects Assessment Program (AOSCEHEAP). Scientific methods used in the Fort McMurray study were initially developed elsewhere[22] and have since been improved upon by Alberta Health & Wellness and other researchers.[23,24]

The AOSCEHEAP[25] provides valuable "baseline" scientific information on amounts of air pollutants that people in Fort McMurray were exposed to and amounts indoors and outdoors of their homes during 1997 and 1998. Fort McMurray makes up approximately 95% of the population within the Wood Buffalo Region. The Regional Municipality of Wood Buffalo has a number of smaller communities that are near (e.g. less than 25 km) to current and proposed oil sand development projects. Also, First Nation people in the region follow traditional patterns of hunting, fishing, and trapping.

People in these communities and First Nation people are uncertain about change that industrial and commercial developments and population growth may have on air quality and their quality of life. A number of common air pollutants are associated with oil sand development project emissions. HEMP is designed to gather information on people's exposure and air quality in a number of communities.

4.1 Recruitment and Sample Selection

Sampling Seasons

Outdoor temperatures, indoor concentrations, and human time activities (e.g., time spent indoors versus time spent outdoors) vary between seasons. Two sampling periods – winter and summer months – will be used by HEMP to measure exposure representing the greatest variation among these factors.

Recruitment of Volunteers

HEMP will recruit unpaid volunteers over the age of 18 years from several Regional Municipality of Wood Buffalo communities. These communities include:

- Fort McMurray
- Mikesew Cree First Nation and the Athabasca Chipewyan First Nation (in Fort Chipewyan)
- Chipewyan Prairie First Nation (in Janvier)
- Fort McKay First Nation
- Fort McMurray First Nations – Anzac/Gregoire Lake

Several approaches to recruit volunteers may be used and are summarized below:

- **Convenience Sampling** – This approach involves active recruitment through advertising in local media and at other venues. These venues include making presentations at industries, educational institutions, recreational facilities, and other public meetings. Recruitment materials (e.g., brochures, community presentations, information bulletins and website) have been developed by the WBEA Human Exposure Monitoring Committee to assist with this. The convenience sampling approach can be efficiently used to select volunteers in the study of a large community like Fort McMurray.
- **Probability Sampling** – This approach involves randomly identifying and recruiting people to participate in the study.[26] Studies in the community of Fort McKay[27,28,29] have shown that the probability sampling approach can be efficiently used to select volunteers in small communities. This method works by dividing all the houses in a small community into equal sections and randomly selecting a similar amount of houses in each section. Prior to recruitment, an information letter is delivered to each house indicating that a study is being undertaken and that they may be asked to participate. A door-to-door campaign is then used to recruit volunteers.

Sample Size and Selection

A minimum of 30 people in a community was identified as a target sample size for HEMP studies. A statistical theory – the Central Limit Theorem – states that as sample size increases, the distribution of the sampling average will approach a normal distribution. It is on this foundation that much of the scientific basis for statistical testing rests. It is important to ensure that a sample is large enough to have results approximate the normal distribution. A sample size of 30 is usually considered adequate for this purpose.[30]

All volunteers will be older than 18 years of age and the objective would to have a sample that follows typical age-gender stratification within each community being monitored. This means 50% of sample ideally will be female and 50% male with approximately 10% of the sample within nine age categories: 18-25; 25-29; 30-34; 35-39; 40-44; 45-49; 50-54; 55-59; and 60-64. As participants are self selected to be volunteers it is important to not that this sampling pattern may not be achievable.

Smokers are not excluded from participating in a study. Smoking and exposure to environmental tobacco smoke is identified during initial recruitment of all volunteers and in surveys. People's exposure to environmental tobacco smoke is then taken into account during analysis of results. An ideal study design has some smokers participate in the study, but no more than is represented by the percent of population that smokes.

4.2 Program Design

Scientific Direction

HEMP uses a Science Advisory Committee to provide technical direction. This committee will have the responsibility of ensuring that proper scientific methods are used so that reliable data are collected in an on-going manner. This approach was also used to provide technical direction for the Alberta Oil Sands Community Exposure and Health Effects Assessment Program (AOSCEHEAP).[31] This scientific team was led by: Dr. Petros Koutrakis (Harvard School of Public Health, Boston, MA), the late Rein Otson (Health Canada, Ottawa, ON), Dr. Pierre Band (Health Canada, Longueuil, QB), Dr. Tee Guidotti (George Washington University, Baltimore, MD), and Dr. Antero Aitio (World Health Organization, Geneva, Switzerland).

In addition to the Science Advisory Committee, a Science Team facilitated by Alberta Health and Wellness, directs the day to day scientific aspects of HEMP. Again, this is consistent with how day-to-day scientific

aspects of the ASCEHEAP and similar studies were conducted in Alberta. The primary role of the Science Team is to ensure that reliable data are collected on a day-to-day basis and to provide scientific advice about program methods. This team will also be responsible for analysis, interpretation and write-up of the findings.

Contaminants Measured

The selection of the following contaminants measured was based on three criteria: (1) local concern of these air contaminants; (2) national initiatives have placed them as a priority for reduction, have exposure limits and monitoring requirements; and (3) availability of technology to accurately quantify the contaminant. Specifically data were gathered on the following contaminants:

- **Nitrogen dioxide (NO_2)** – a gas that results from combustion; sources include vehicular exhaust, gas stoves, tobacco smoke, kerosene heaters, wood-burning stoves and fireplaces, and gas pilot lights.
- **Sulfur dioxide (SO_2)** – a gas produced by several industrial processes; sources include vehicles, outdoor air, unvented kerosene heaters, and wood-burning heaters and stoves.
- **Ozone (O_3)** – a gas created through the interaction of hydrocarbons, nitrogen oxides, and sunlight; ozone is primarily found in outdoor air, although sources may also include residential electronic air cleaners, negative ion generators, photocopy machines, deodorizers, germicides, and some aerosol sprays.
- **Volatile organic compounds (VOCs)** – a number of compounds that are carbon-based vapors and gases, many of which are produced from chemical reactions; sources include air fresheners, moth balls, polyurethane floor finish, synthetic fabrics, furniture polish, latex paint, floor wax and wax strippers, shoe polish, solvents, particle board, floor and carpet adhesives, fluorescent lighting, and tobacco smoke.
- **Inhalable particulates ($PM_{2.5}$)** – microscopic particles that remain floating in the air and can enter the respiratory system; sources include tobacco smoke, kerosene heaters, home renovations, fabric lint, wood stoves or fireplaces, humidifier deposits, and dander.

Additional Data Sources

In addition to the exposure sampling listed above, all volunteers were requested to complete the following:

- Review and sign a consent form outlining the participant's involvement in the program;
- A survey which collects demographic and identifies potential exposure information from the participants. This can be completed at their convenience during the 7-day monitoring period; and
- A diary of personal activities throughout the 7-day period of participation.

4.3 Program Logistics

Field Staff

The project co-ordinator is responsible for selecting and screening participants, booking appointments for the field monitoring teams, maintaining the sampler inventory, and co-ordinating the flow of samplers to the laboratory for analysis. In addition, the field co-ordinator was responsible for co-ordinating the flow of sampling time information and respondent data, ensuring that all aspects of the program are administered to each of the participants, and ensuring entry of all data electronically into various databases programs.

Field monitoring teams consisted of two trained personnel who were responsible for placing the samplers in an appropriate location in each participant's home, collecting spent samplers, and recording various sources of data. A multi-day training session hosted by HEMP and Alberta Health & Wellness was held for the field monitoring team(s). Classroom training consisted of a review of the program and the requirements for successful completion. Each team member was required to practice and demonstrate the ability to correctly handle and locate samplers in a participant's home.

The field teams will operate in pairs in the field to ensure safety and improve accuracy. Each team will receive a list of participants and appointment times. Each team is responsible for contacting a participant at a pre-arranged appointment time to place the air monitors in a home, outside the home, and on the individual. Upon arrival at a home, the field teams will provide details about equipment being placed in the home and explain what to do if there are problems with the equipment. They will also provide details about the time activity diary and demographic and health survey that a person is required to complete.

Field Procedures

The general procedures for deploying the air quality equipment to a participant and in their home are provided below.

1. Each person initially receives a formal letter from the Project Coordinator. The letter explains what they can expect during their week of participation in the study and contact information if they have any questions.

2. Field monitoring teams then explain the program in detail and answer any questions or concerns people may have. Samples of the monitoring equipment are shown and typical placements in the homes are explained. The purpose of the time activity diary and demographic and health survey are also explained.

3. Each person is then required to sign a consent form. In signing the form, they must volunteer to make themselves available to allow field monitoring teams to place and remove monitoring equipment at the beginning and end of a consecutive seven-day period. They must also volunteer to complete the time activity diary and demographic and health survey.

4. Appointment times for placing and removing the air monitoring equipment in a person's home are set.

5. At an agreed upon time, field teams place air monitoring equipment at each person's home. These monitors remain for a seven-day sampling period. The time activity diary and demographic and health survey is given to each person to complete.

6. Field monitoring teams remove the monitoring equipment at the end of the seven-day period. In addition, the completed time activity diary and demographic and health survey is collected.

7. At the end of field work, study personnel separate the consent forms from other documents, sorted by identification number. The consent forms are filed in secured storage. Since these forms contain names and links to other data collected in the field, they are kept separate from other information to assure confidentiality of information.

Chain of Custody

Chain of custody is defined as the documentation of movement and location of samples from the time it is collected to the time it is analyzed at a laboratory. HEMP will use chain of custody forms (log sheets) to track and ensure proper movement of field samples to the laboratories for analysis.

Data Entry and Analysis

All information collected by the field staff was returned to the program office at the end of the day. The project co-ordinator reviewed it to verify completeness and, if necessary, follow-up with the participant to complete any missing information. Data was entered by the project co-ordinator. The project co-ordinator then sent the electronic and paper files to Alberta Health and Wellness where a database co-ordinator verified data entry and cleaned records. Once data entry was completely verified, the electronic files were compiled and merged as necessary into a database for analysis.

All data components were made identifiable by the arbitrarily assigned participant identification number only; other identifiable information was stripped from the records to ensure confidentiality of the results. Data analysis was then conducted by the science team at Alberta Health and Wellness offices using and *SPSS (version 14.0)* statistical packages. Alberta Health and Wellness retains all records and results pertaining to an individual personal and health information as per applicable provincial legislation.

4.4 Exposure Monitoring Procedures

Monitoring Equipment

Passive Air Monitors

Nitrogen Dioxide (NO_2): A passive air monitor was used for measuring nitrogen dioxide. The clip-on air monitor contains a chemical adsorbent that collects nitrogen dioxide indicators by passive diffusion.

Sulfur Dioxide (SO_2): A passive air monitor was used for measuring sulfur dioxide. The clip-on air monitor contains a chemical adsorbent that collects sulfur dioxide indicators by passive diffusion.

Ozone (O_3): A passive air monitor was used for measuring ozone. The clip-on air monitor contains a chemical adsorbent that collects ozone indicators by passive diffusion.

Volatile Organic Compounds (VOCs): A passive air monitor was used for measuring a variety of VOCs. The clip-on air monitor contains a chemical adsorbent that collects various VOCs by passive diffusion.

All four passive air monitors were designed to be worn in the participant's breathing zone to measure personal exposure. The participants were encouraged to continue normal activities while wearing the monitor. During activities such as sleeping or showering, however, the sampler was to be kept as near to the person as practical while protecting the sampler from damage and high humidity environments.

One of each type of sampler was deployed inside and outside the participant's home using a stationary stand constructed to house and shelter the monitors during the 7-day exposure period. The air monitors were attached to identically construct indoor and outdoor stationary stands approximately one (1) metre above the floor or ground. The outdoor passive air monitoring stand has a rain shield approximately 30cm in diameter for shelter.

The method detection limits (MDL) of the passive samplers were based on field blanks and the limit of quantitation of the laboratory analysis. The detection limits for VOCs were based on the laboratory limit of quantitation (150 ng/sampler) when more than 90% of the field blanks were less than the limit of quantitation and are indicated by an asterisk in the table. For the other compounds, the detection limit was based on three standard deviations of the field blank levels and may vary slightly between the batches of samplers through the program. The detection limits for the compounds investigated (assuming a 7-day sample) are listed in the third column of Table 2. Columns 4 to 6 in the table show the fraction of the measurements (or monitors) that were below the detection limits. Despite not being measurable, failure to detect a particular component remains useful in characterizing community exposures.

Table 1: Summary of Passive Sampler Detection Limits – 2005 Monitoring Year

Sampler Compound	Sample Rate (ml/min)	Detection Limit (µg/m^3)	Fraction of samples less than MDL		
			Personal	Indoor	Outdoor
NO_2	120	2.1	0 %	0%	1.7%
SO_2	218	1.1	74.1%	96.6%	25.4%
O_3	24.5	0.82	13.8%	35.6%	0%
Benzene	35.5	0.42*	0%	0%	1.7%
Decane	23.1	0.64*	3.4%	8.5%	79.7%
Ethylbenzene	27.3	0.55*	0%	1.7%	47.5%
Heptane	28.9	0.51*	18.6%	28.8%	52.5%
Hexane	32	2.2	45.8%	62.7%	98.3%
Limonene	30	0.50*	0%	0%	86.4%
3-Methylhexane	28.9	0.51*	6.8%	13.6%	55.9%
m-, *p*-Xylene	27.3	1.0	1.7%	1.7%	32.2%
N-propylbenzene	24.6	0.60*	32.2%	47.5%	93.2%
Nonane	24.6	0.60*	13.6%	37.3%	94.9%
Octane	26.6	0.56*	5.1%	5.1%	66.1%
o-Xylene	27.3	0.55*	1.7%	5.1%	45.8%
Toluene	31.4	2.6	0%	1.7%	64.4%

** Detection limit based on laboratory limit of quantitation (150 ng/sampler) assuming 7-day sample period.*

Active Air Monitors

For measurement of respirable particulates such as particulate 2.5µm from indoor and outdoor environments at the participant's home, the stationary indoor and outdoor air particulate pumps were used to house particulate sampling heads and filters. The particulate sampling heads were oriented in a position that avoided particle

deposition due to gravity and were attached to the particulate pumps approximately one (1) metre above the floor or ground. Before and after exposure monitoring, the particulate filters were weighed, and the information was recorded along with the filter identification numbers for analysis purposes after the 7-day exposure period.

Sampler Placement Strategy

All sampler locations were determined during the initial visit to each home. Locations were selected after carefully determining the layout of the home, based on the daily habits of the participant, the type of dwelling (home, apartment, etc.), and the outside layout of the yard or grounds. Samplers were placed in the main living area of the participant (the room in which the participant spends the most time while awake), ensuring that the samplers were at least two metres away from exterior doors, windows, and ventilation registers. The field teams are responsible in drawing a floor plan of the participant's residence to identify the location of the indoor sampler unit, for future reference during analysis of the participants data.

The protocol specifies that the participant's backyard is the preferred location for outdoor sampling and that the monitors should not be located within one metre of trees and bushes or within five metres of any type of air vent. For second floor apartments, a "yardarm" was deployed from a window or balcony to support the sampling devices. If a yardarm was not possible, the protocol considers collection of samples at ground level acceptable for second floor apartments. Non-ideal situations required some reasonable compromises, but were identified by the field teams for consideration during data analysis.

4.5 Reporting

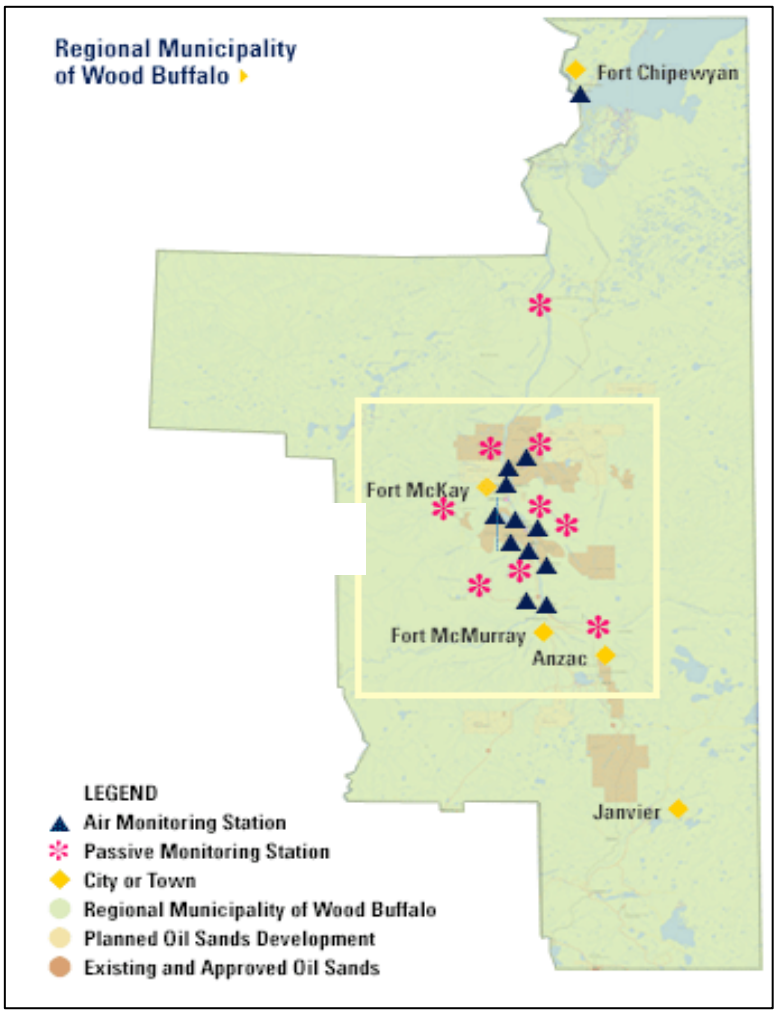
Alberta Health & Wellness will be responsible for preparing periodic reports for HEMP. Along with this important responsibility will be interpretation and communication of the findings to HEMP. HEMP will be responsible for communicating findings of the studies to the public in the Wood Buffalo region.

Part II – 2005 Monitoring Year Results

1.0 Characteristics of Sample

The Wood Buffalo Environmental Association – Human Exposure Monitoring Program (WBEA-HEMP) is operated in northeastern Alberta (see Figure 1) and within the Regional Municipality of Wood Buffalo. The major communities within the boundaries include the City of Fort McMurray, the towns of Fort McKay and Fort Chipewyan as well as the first nation communities of Mikesew Cree, Athabasca Chipewyan, Chipewyan Prairie and Fort McMurray #468. For the 2005 monitoring year, personal exposure monitoring was conducted in the City of Fort McMurray and the town of Fort Chipewyan. Figure 1 also provides information about WBEA's air monitoring stations, communities and existing and proposed oil sand projects.

Figure 1: Overview of Human Exposure Monitoring Program Area



1.1 Age and Gender

The HEMP protocol as described in Part I of this document requires a minimum of 30 people in a community necessary to ensure that a sample is large enough to represent the community at large. For the 2005 monitoring year, 29 participants were from the City of Fort McMurray and 30 participants from the town of Fort Chipewyan. Within the Fort McMurray sample, the majority of the sample, 69% (20/29) were female with only 9 (31%) male participants. For Fort Chipewyan, again the majority of the participants 63% (19/30) were female, with 37% (11/30) were male. Figure 2 shows the gender distribution of the two samples taken from Fort McMurray and Fort Chipewyan.

Figure 2: Gender Distribution

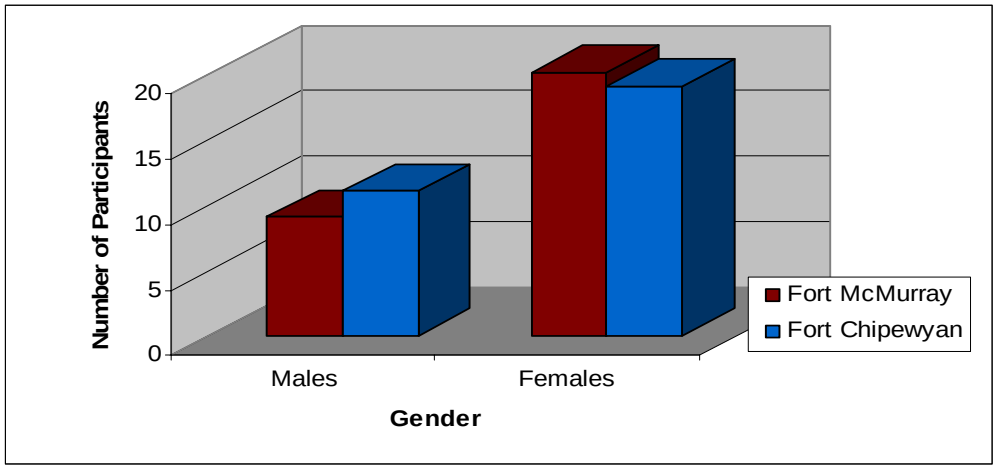
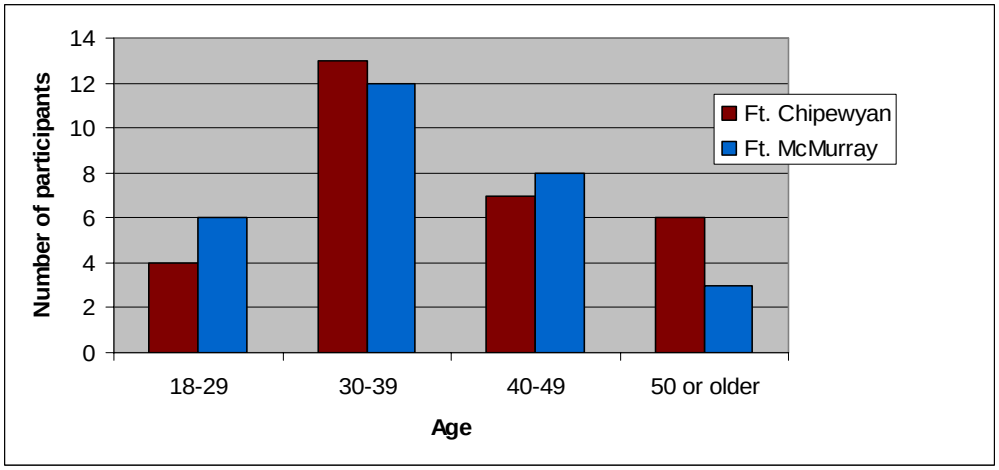


Figure 3 describes the age distribution of the participants from each sample. The majority of the participants were between the ages of 30-39 for both sample populations, 41.3% in the Fort McMurray sample versus 43.3% in the Fort Chipewyan sample. The lowest numbers of participants for Fort Chipewyan were between the ages of 18 – 29 whereas for Fort McMurray the fewest participants were seen in the 50 or older category.

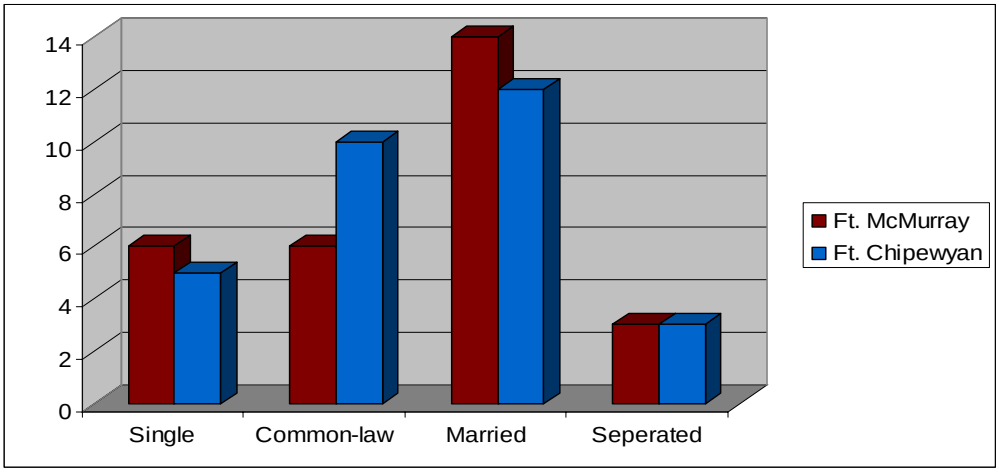
Figure 3: Age Distribution



1.2 Marital Status

Participants in the program were asked about their marital status. As demonstrated in Figure 4, both sample groups have a similar distribution with the majority of each sample either married or in a common law relationship.

Figure 4: Marital Status



1.3 Education Level

Table 2 below shows the distribution of education level of the two sample groups into five categories. It should be noted participants who indicated they attended either any college or university program were included in that category regardless of its completion or awarding of a degree. The results presented in Table 2 are also presented in proportions to ensure the privacy and confidentiality of the respondents.

This table shows that the two samples do significantly vary in terms of education status. A higher proportion of participants from Fort McMurray (96.5%) indicated being involved in advanced education or developing trade skills than participants from Fort Chipewyan (73.3%).

Table 2: Highest Level of Education

Community	Less than High School (%)	Completed High School (%)	Trade Certificate or Diploma (%)	College (%)	University (%)
Fort McMurray	0	3.4	13.8	17.2	65.5
Fort Chipewyan	20.0	6.7	6.7	40.0	26.6

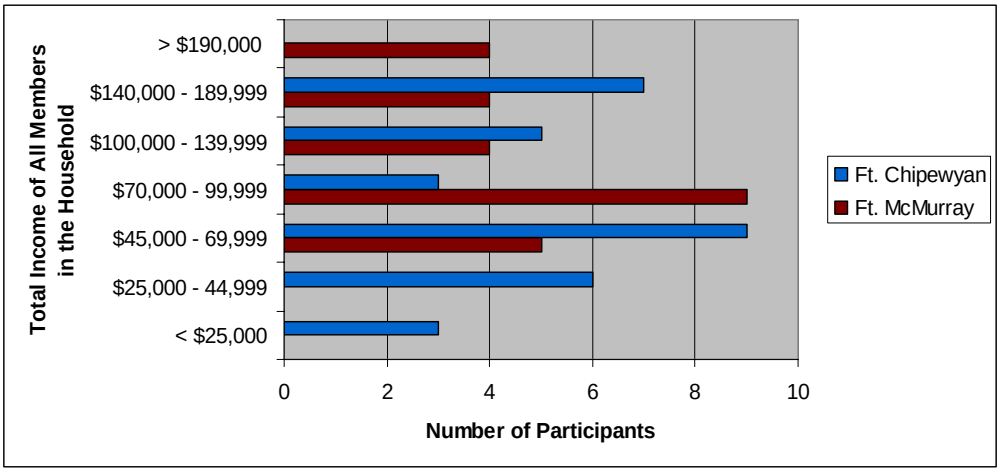
1.4 Occupation

All participants from Fort McMurray indicated they were had a paid job outside of the home, whereas only 76.7% (23/30) of the Fort Chipewyan residents indicated this response. The remaining proportion of participants from Fort Chipewyan indicated they were retired, homemakers or full-time students. In both samples, the majority of participants indicated their employment status was full-time, 93.1% for Fort McMurray versus 73.3% of Fort Chipewyan participants. Due to the variety of occupations held by the participants, creating meaningful categories without identifying an individual was not achievable.

1.5 Total Household Income

In Figure 5, the total income of the two sample groups are shown. As illustrated, the Fort Murray sample has a higher level of income compared to the Fort Chipewyan sample.

Figure 5: Total Household Income



1.6 Smoking

All the participants were asked about their exposure to tobacco smoke in the past and currently as regular exposures to tobacco smoke significantly impacts not only an individual's health but as well the increases the levels of contaminants detected by the air monitoring equipment used in this study. In the past, 17.2% (5/29) of Fort McMurray respondents reported they smoked as much as one cigarette a day for at least a year. In comparison, 43.3% (13/30) of Fort Chipewyan participants reported the same usage of tobacco products. Of those who are or were smokers, 17.2% (5/29) of the Fort McMurray versus 36.7% (11/30) of Fort Chipewyan participants smoked between one (1) and twenty (20) cigarettes per day.

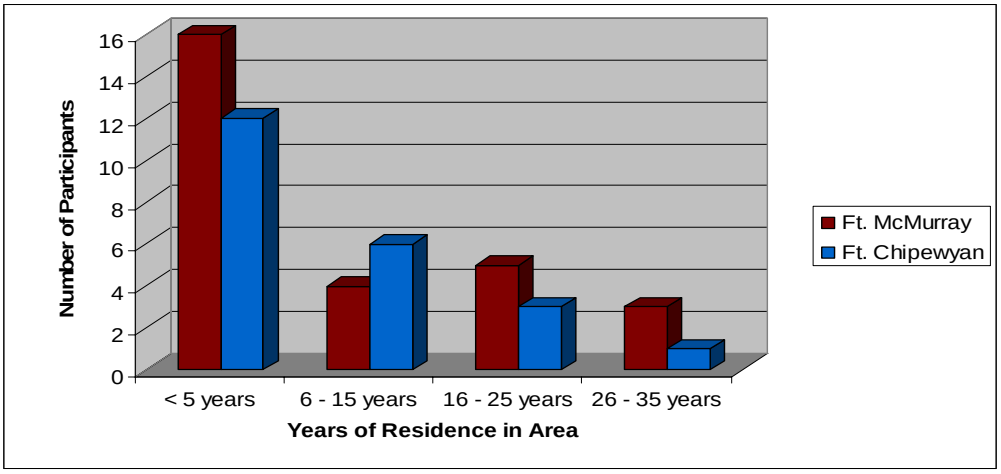
In August 2005, Health Canada indicated the lowest national smoking rate in Canadian history at 20%, which was mirrored in Alberta with a 20% current smoker rate. At the time of this monitoring project, 10.3% (3/29) of Fort McMurray participants currently smoke, whereas 26.7% (8/30) of the Fort Chipewyan participants are current smokers.

The participants were also asked if they permitted smoking in their home or vehicle. Approximately one-quarter (24.1%; 7/29) of Fort McMurray participants allowed smoking in their home and 20.7% allowed smoking in their vehicle. In contrast, 26.7% (8/30) participants within the Fort Chipewyan sample allowed smoking in their homes, with 20.0% (6/30) allowing smoking in their vehicle.

1.7 Length of Residence

Within the Demographic and Exposure Survey, participants were asked to indicate their address at birth and provide their history of residence throughout their lifetime. Figure 6 graphically demonstrates the length of residency for each community sample. The majority of the participants have resided in either community for less than five (5) years. For the remaining residency categories, the number of participants in each group varies as shown in the figure below.

Figure 6: Length of Residence

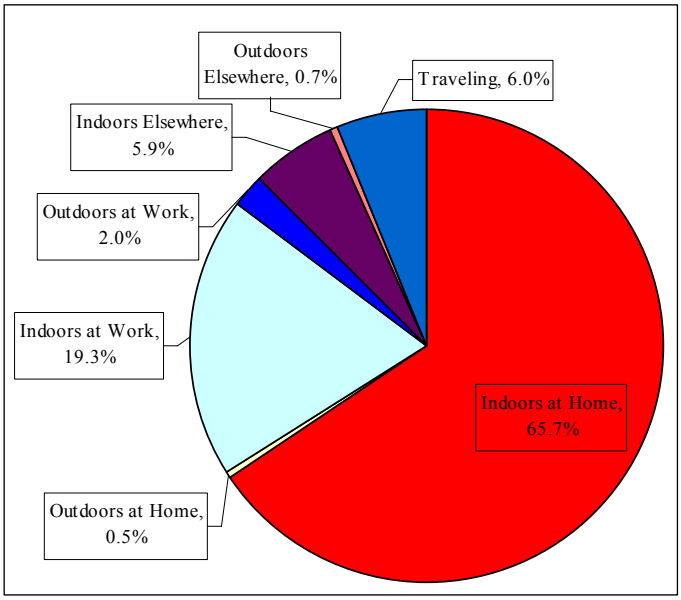


1.8 Time Activity Diaries

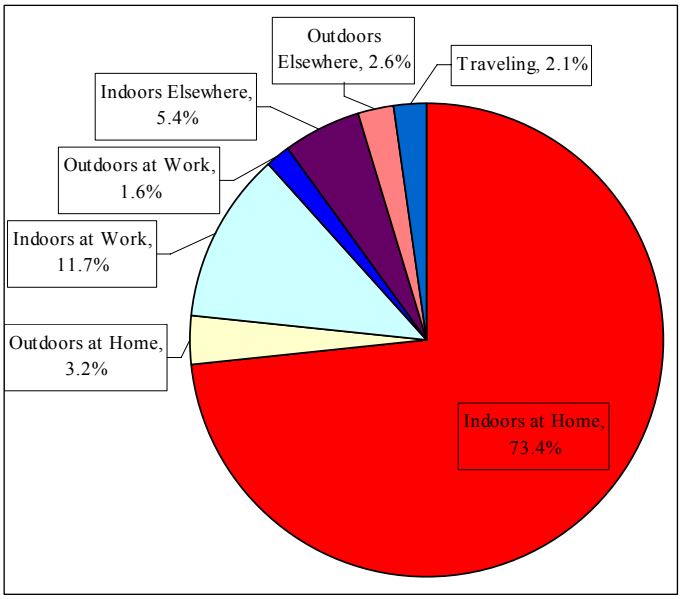
Participants were asked to record time spent at various mutually exclusive locations for the duration of their participation. Figure 7 represents how time was spent for each community sample. Overall, the majority of a participant's time was spent indoors at home 65.7% for Fort McMurray participants, with it being slightly higher for Fort Chipewyan participants at 73.4%. Fort McMurray participants also spent a higher proportion of their time indoors at work or traveling compared to Fort Chipewyan participants.

Figure 7: Average Proportion of Time Spent in a Day by Participants

Fort McMurray Participants



Fort Chipewyan Participants



2.0 Air-Borne Contaminants

2.1 Passive Samplers

Passive air quality measurements were taken with four separate samplers, each deployed for a one-week period throughout the program period. Each participant carried samplers around their neck hanging in their breathing zone (**personal sampler**), had a sampler deployed inside their home (**indoor sampler**), and had a sampler deployed in the environment immediately outside their home (**outdoor sampler**). Table 3 shows the sampler types and the chemicals monitored by each sampler.

Table 3: Samplers and Chemical Concentrations Measured

Sampler	Chemical Concentrations Measured
NO_2	Nitrogen Dioxide
SO_2	Sulfur Dioxide
O_3	Ozone
Volatile Organic Compounds	Benzene
	Decane
	Ethylbenzene
	Heptane
	Hexane
	Limonene
	3 - methylhexane
	m,-p – xylene
	N - propylbenzene
	Nonane
	Octane
	o - xylene
	Toluene

The Field Team(s) deployed 948 passive air monitors throughout the 16 week sampling period. Three of these monitors were replacements for ones that had been damaged or lost by the participant. Table 4 shows how the remaining 944 passive monitors were distributed.

Table 4: Distribution of Passive Air Monitors

Number by Location	Number by Type
236 Personal	59 NO_2
	59 SO_2
	59 O_3
	59 VOCs
236 Indoor	59 NO_2
	59 SO_2
	59 O_3
	59 VOCs
236 Outdoor	59 NO_2
	59 SO_2
	59 O_3
	59 VOCs
236 Blank	59 NO_2
	59 SO_2
	59 O_3
	59 VOCs
Total	**944**

Calculation of the concentrations of each chemical from the amount of material detected on each sampler filter involved formulae relating sampling rates to concentration levels. In addition, a time correction was applied to correct for the precise amount of time (in minutes) that the samplers were exposed to air. A correction for blank levels (levels measured on unexposed sampler filters) was also applied. This correction itself involved an examination of the variability of the blank values over the course of the program, and for some chemicals resulted in a complex time dependent correction.

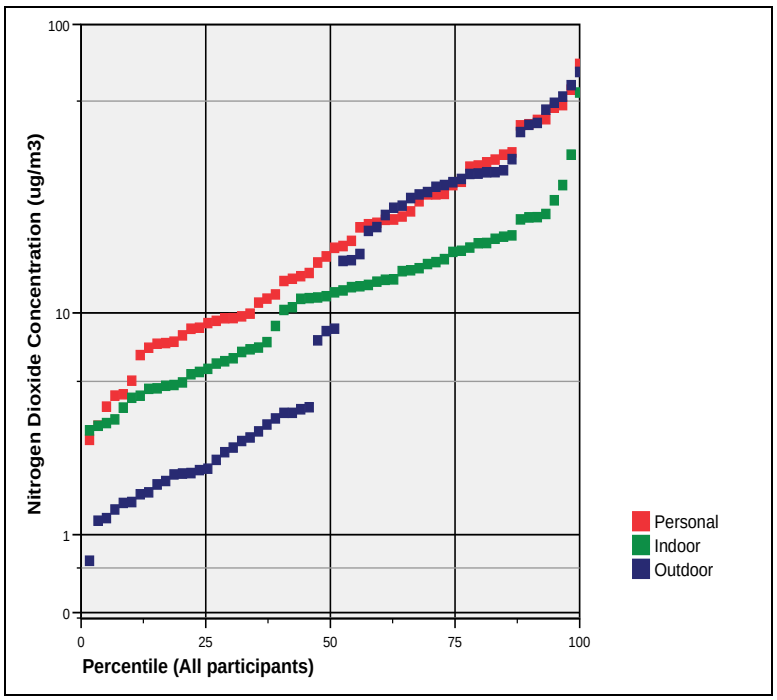
In the section that follows, the distribution of all measures taken throughout the 2005 monitoring year in the communities of Fort McMurray and Fort Chipewyan for each of the sampler types: personal, indoor and outdoor are present. The plot in the graph is the calculated average concentration in the air to which the sampler was exposed against the percentile of this exposure level in the particular sample type across all samples collected. The median exposure level is located at the point where a vertical line drawn from the 50th percentile mark on the horizontal axis intersects with the curve. The concentration level at that point is read from the vertical axis by drawing a horizontal line from that point on the curve to the vertical axis. The vertical axis is presented as a logarithmic scale that reflects the general finding of positive skew in distributions of chemicals in air. If the line deviates from a straight line and especially if the curvature is marked at either end (usually the end indicating higher exposure levels), this indicates a skewed distribution of exposure to that chemical more marked than the log normal distribution. The degree of slope in the linear section of the curve is related to the overall variability of the sample such that steeper slopes indicate more variable distributions. Curves that do not appear to start at percentile 0 indicate that a proportion of cases fell below the blank level for the sampler for that chemical. The proportion of samples for which this is true is determined by noting the percentile level at which the curve begins.

Nitrogen Dioxide (NO_2)

In Alberta, nitrogen dioxide emissions are produced by vehicles, industry sources (oil and gas) and power plants. More localized sources of exposure are natural gas combustion, heating fuel consumption and forest fires. The method detection limit (MDL) for the NO_2 sampler is 2.1 $\mu g/m^3$ with all personal and indoor samplers reporting above the minimum detection limit. For the outdoor samplers, a minor fraction (<2%) were below the detection limit. While the imprecision associated with individual outdoor samples increases dramatically when measures fall below the detection limit, the data provides a prediction of overall community exposure and is utilized for each contaminant.

Figure 8 shows the cumulative distribution of NO_2 concentrations for the three types of samplers (personal, indoor, and outdoor) for all participants of the 2005 monitoring year. Concentrations measured on the personal samplers were slightly higher than either the outdoor or indoor samplers, but as shown in the graph the differences were not significantly higher. This graph also demonstrates a separation in the distribution of the outdoor samplers, which reflects the use of two different samples.

Figure 8: Distribution of Nitrogen Dioxide – All Participants



Figures 9 and 10 each show the distribution of nitrogen dioxide in each of the participating monitoring communities. In Figure 9, the median concentration measured on the personal samplers for participants in Fort McMurray is slightly lower than those measured for the outdoor samplers. Indoor levels were significantly lower. In Figure 10, the concentrations measured on the personal samplers for participants in Fort Chipewyan were slightly higher than indoor samplers, with lower outdoor concentrations.

Figure 9: Distribution of Nitrogen Dioxide – Fort McMurray Participants

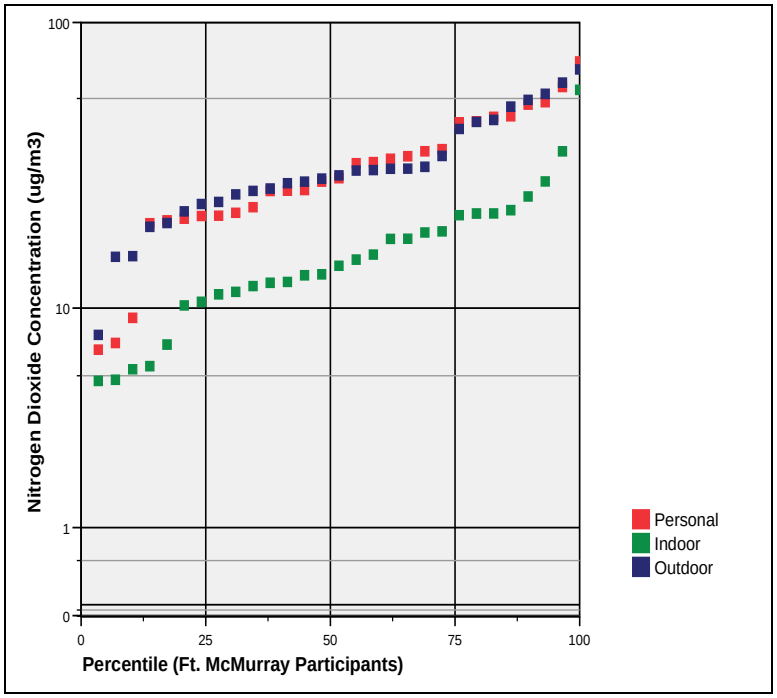
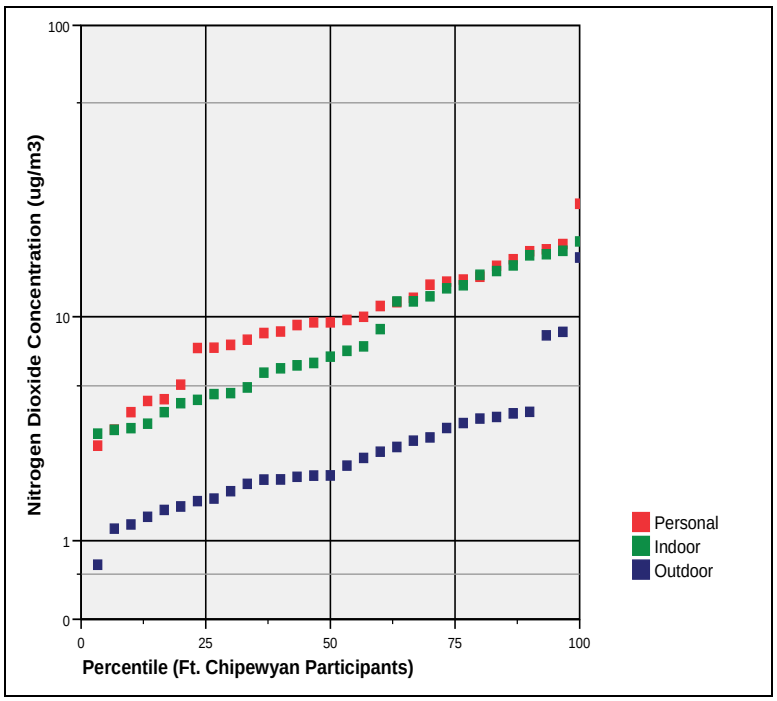


Figure 10: Distribution of Nitrogen Dioxide – Fort Chipewyan Participants



In the following tables, the median and 95th percentile NO_2 levels are summarized for each location and compared to applicable guidelines or past programs. For all participants as noted in Table 5, the median and 95th percentile of this contaminant is below acceptable guidelines.

Table 5: Comparison of NO_2 Levels in µg/m^3 with Guidelines – All Participants

Parameter	Year	Personal	Indoor	Outdoor
All Participants Median	2005	17.1	11.9	18.1
All Participants 95th Percentile	2005	53.3	28.4	57.0
Guideline/Reference Level		N/A	100 (long term)[ii] 480 (hour)[ii]	200 (24 hour)[i]

i: Alberta's Ambient Air Quality Objectives, 2005 ii: Health Canada, 1989

Fort McMurray

As noted in the introduction, a baseline program was conducted in 2000 in the community of Fort McMurray. Through statistical testing (Mann-Whitney) it was determined the 2000 and 2005 monitoring samples for each year are comparable. Table 6 shows the median and 95th percentile of NO_2 (µg/m^3) for the city of Fort McMurray. The median of the 2005 Fort McMurray sample was higher than the 2000 Alberta Oil Sands median for all three types of samplers. This increase may be a reflection of an increased population, vehicle emissions and industrial activity in this community. However, despite this increase the levels reported are below applicable guidelines.

Table 6: Comparison of NO_2 Levels in µg/m^3 with Guidelines - Fort McMurray Participants

Parameter	Year	Personal	Indoor	Outdoor
Fort McMurray Median	2005	29.1	14.3	29.8
Fort McMurray 95th Percentile	2005	66.9	47.5	65.7
Alberta Oil Sands Median	2000	15.9	8.6	9.5
Alberta Oil Sands 95th Percentile	2000	53.2	20.0	38.5
Guideline/Reference Level		N/A	100 (long term)[ii] 480 (hour)[ii]	200 (24 hour)[i]

i: Alberta's Ambient Air Quality Objectives, 2005 ii: Health Canada, 1989

Fort Chipewyan

The median personal level of nitrogen dioxide for the 2005 Fort Chipewyan sample is approximately one third of the level of the 2005 Fort McMurray sample. It should be noted that for the 2005 Fort Chipewyan sample, the 2000 Alberta Oil Sands data is not comparable as this program was only deployed in the Fort McMurray area. However, like the 2005 Fort McMurray sample, the indoor and outdoor levels detected are lower than the accepted guideline or reference levels.

Table 7: Comparison of NO_2 Levels in µg/m^3 with Guidelines – Fort Chipewyan Participants

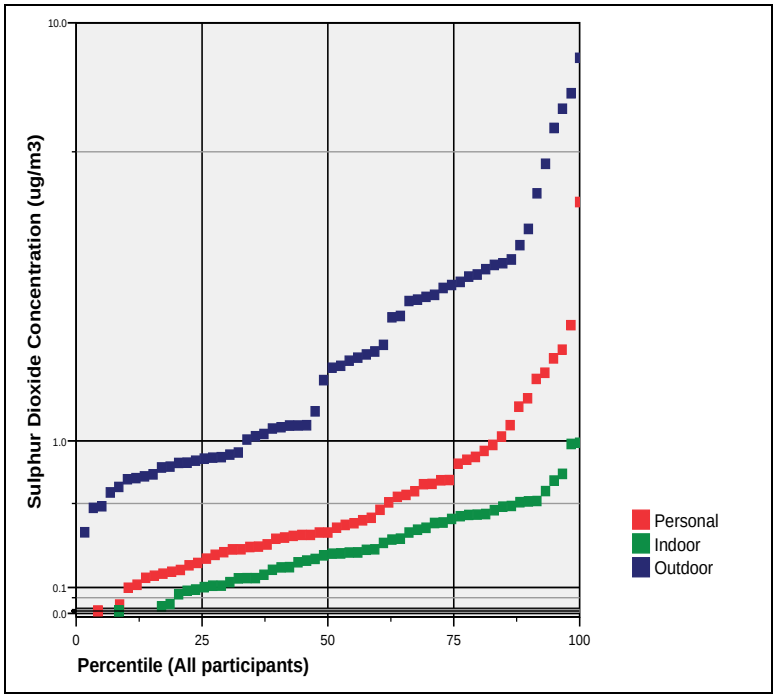
Parameter	Year	Personal	Indoor	Outdoor
Fort Chipewyan Median	2005	9.6	7.3	2.4
Fort Chipewyan 95th Percentile	2005	21.2	17.7	12.2
Guideline/Reference Level		N/A	100 (long term)[ii] 480 (hour)[ii]	200 (24 hour)[i]

i: Alberta's Ambient Air Quality Objectives, 2005 ii: Health Canada, 1989

Sulfur Dioxide (SO_2)

Sulfur dioxide is formed during the processing and combustion of fossil fuels containing sulfur. Industries involved in producing SO_2 include gas plant flares, oil refineries, pulp and paper mills, fertilizers plants, coal-fired power plants, and power generating stations. Figure 10 shows the cumulative distribution of SO_2 concentrations for the three types of samplers (personal, indoor, and outdoor) for all participants. The MDL of SO_2 is 1.1 $\mu g/m^3$, with a significant portion of the personal (74.1%) and indoor (96.63%) below this limit. The majority of outdoor samplers (74.6%) were above the MDL. As is shown in Figure 11, outdoor concentrations of SO_2 were highest in outdoor air and lowest in home indoor environments. The median outdoor concentrations are approximately four orders of magnitude the personal and indoor concentrations.

Figure 11: Distribution of Sulfur Dioxide – All Participants



Figures 12 and 13 show the distribution of SO_2 in each of the two sampling communities. For both community samples taken, and as shown in Figure 11, the highest concentration in each individual community was detected in the outdoor concentrations. The lowest levels were seen in indoor environments.

Figure 12: Distribution of Sulfur Dioxide – Fort McMurray Participants

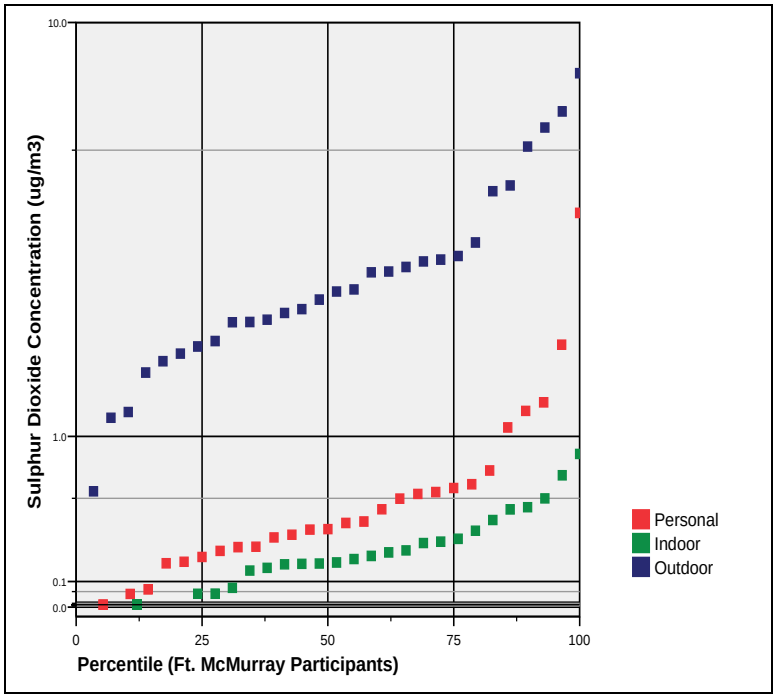
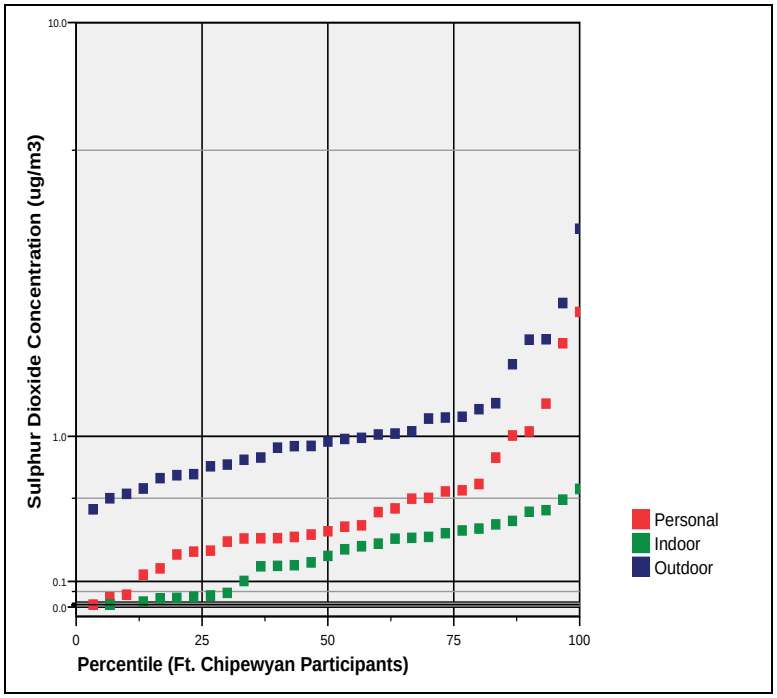


Figure 13: Distribution of Sulfur Dioxide – Fort Chipewyan Participants



As in NO_2, the following tables describe the median and 95th percentile SO_2 levels each location and are compared to applicable guidelines or past programs. For all participants as noted in Table 8, the median and 95th percentile of this contaminant is below acceptable guidelines.

Table 8: Comparison of SO_2 Levels in µg/m^3 with Guidelines - All Participants

Parameter	Year	Personal	Indoor	Outdoor
All Participants Median	2005	0.4	0.3	1.7
All Participants 95th Percentile	2005	1.9	0.7	6.8
Guideline/Reference Level		N/A	50 (long term)[i] 1000 (5 min)[i]	150 (24 hour)[ii]

i: Health Canada, 1989 ii: Alberta's Ambient Air Quality Objectives, 2005

Fort McMurray

In Table 9 the median and 95th percentile concentrations determined from the 2005 Fort McMurray sample in comparison to the 2000 Alberta Oil Sands results are presented. The levels detected in 2005 are lower than those in 2000 and than applicable guidelines.

Table 9: Comparison of SO_2 Levels in µg/m^3 with Guidelines - Fort McMurray Participants

Parameter	Year	Personal	Indoor	Outdoor
Fort McMurray Median	2005	0.4	0.2	2.6
Fort McMurray 95th Percentile	2005	3.1	0.8	7.3
Alberta Oil Sands Median	2000	0.9	0.4	1.6
Alberta Oil Sands 95th Percentile	2000	5.6	4.1	8.0
Guideline/Reference Level		N/A	50 (long term)[i] 1000 (5 min)[i]	150 (24 hour)[ii]

i: Health Canada, 1989 ii: Alberta's Ambient Air Quality Objectives, 2005

Fort Chipewyan

The median and 95th percentile concentrations from Fort Chipewyan (Table 10) are lower than those observed for the 2005 Fort McMurray samples. Again, it should be noted that the 2000 Alberta Oil Sands Program data is not comparable for the 2005 Fort Chipewyan sample as they are from separate populations. The levels of SO_2 measured in each community were much lower than accepted guidelines. Of note, personal exposure levels to sulfur dioxide were the same as the Fort McMurray participants even though outdoor concentrations were lower.

Table 10: Comparison of SO_2 Levels in µg/m^3 with Guidelines - Fort Chipewyan Participants

Parameter	Year	Personal	Indoor	Outdoor
Fort Chipewyan Median	2005	0.4	0.2	1.0
Fort Chipewyan 95th Percentile	2005	2.1	0.6	3.0
Guideline/Reference Level		N/A	50 (long term)[i] 1000 (5 min)[i]	150 (24 hour)[ii]

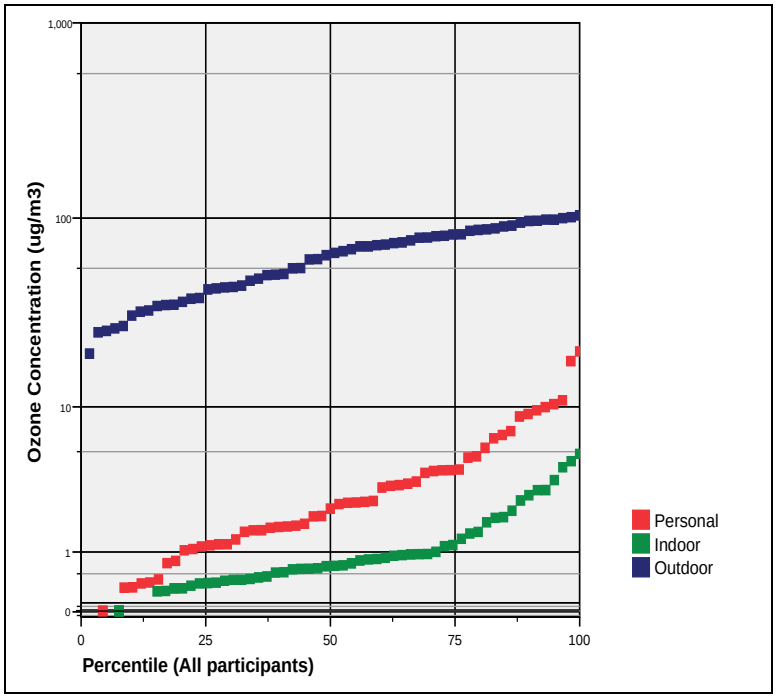
i: Health Canada, 1989 ii: Alberta's Ambient Air Quality Objectives, 2005

Ozone

Ozone is a naturally occurring gas, generated in the higher layers of the atmosphere but is also produced indirectly by industrial activities. Ground level ozone is generated by a photochemical reaction of oxides of nitrogen (NO_x) and volatile organic compounds (VOCs). The MDL for the ozone samplers is 0.82 µg/m^3 with all outdoor samplers detecting levels of ozone above this limit. However, 13.8% of personal, and 35.6% indoor samplers were below the detection limit.

Figure 14 shows the cumulative distribution of ozone concentrations for the three types of samplers and of all participants. The median outdoor concentrations were over one order of magnitude higher than the personal and indoor concentrations. Scientific research has determined outdoor and ambient levels of ozone exposure are commonly higher than those detected at the personal level.[32] An explanation for this difference could be a reflection as to how ozone is destroyed as it chemically reacts with other components in the air. These findings reveal the inherent inaccuracy of using ambient concentration levels as a reflection of personal exposure.

Figure 14: Distribution of Ozone – All Participants



In Figure 15 and 16, the distribution of ozone for each community is presented.

Figure 15: Distribution of Ozone – Fort McMurray Participants

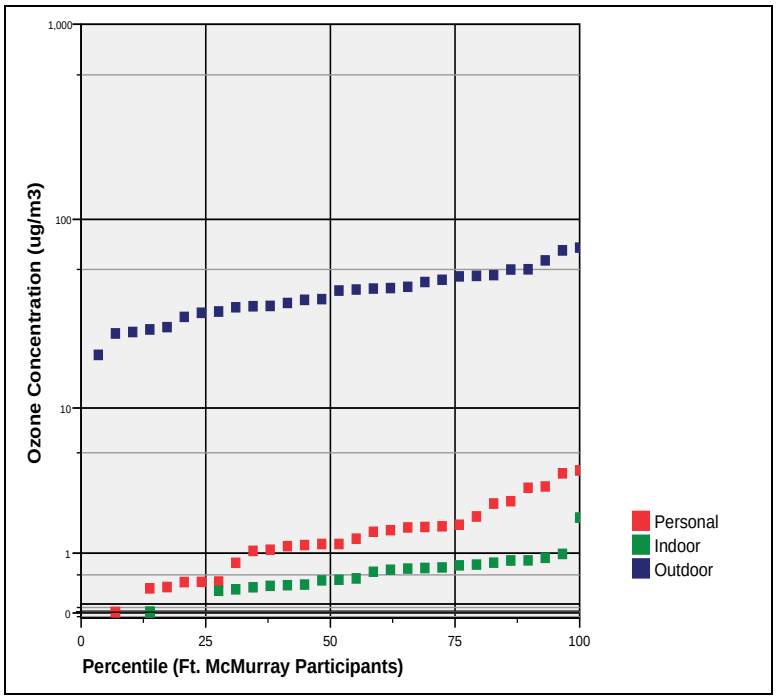
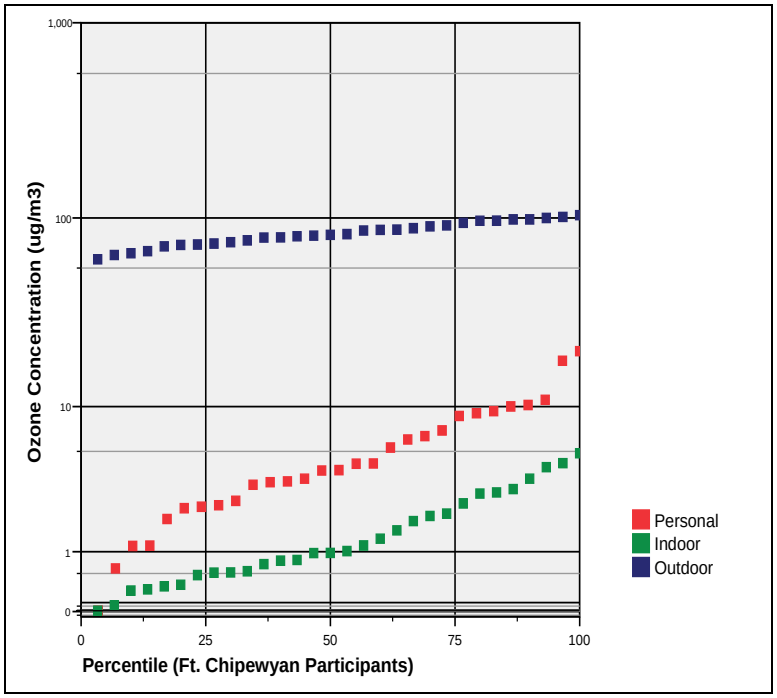


Figure 16: Distribution of Ozone – Fort Chipewyan Participants



For ozone, the following tables describe the median and 95th percentile levels for each location and are compared to applicable guidelines or past programs. For all participants as noted in Table 11, the median and 95th percentile of this contaminant is below acceptable guidelines.

Table 11: Comparison of O_3 Levels in µg/m^3 with Guidelines – All Participants

Parameter	Year	Personal	Indoor	Outdoor
All Participants Median	2005	2.4	0.7	66.1
All Participants 95th Percentile	2005	11.2	4.4	100.0
Guideline/Reference Level		N/A	240(hour)[i]	160 (one hour)[iii] 125 (8 hour)[ii]

i: Health Canada, 1989 ii: Canada-wide standard, 2010 iii: Alberta's Ambient Air Quality Objectives, 2005

Fort McMurray

Table 12 describes the sampler results for the 2000 and 2005 samples from the City of Fort McMurray. . The personal and indoor median and 95th percentile concentrations determined from the 2005 Fort McMurray sample in comparison to the 2000 Alberta Oil Sands results are lower. A slight increase in outdoor ozone levels occurred during the 2005 Fort McMurray sampling period when compared to the 2000 results. Again, the detected levels are below recognized guideline or reference levels.

Table 12: Comparison of O_3 Levels in µg/m^3 with Guidelines – Fort McMurray Participants

Parameter	Year	Personal	Indoor	Outdoor
Fort McMurray Median	2005	1.2	0.5	42.7
Fort McMurray 95th Percentile	2005	4.2	1.5	70.3
Alberta Oil Sands Median	2000	3.3	2.4	39.0
Alberta Oil Sands 95th Percentile	2000	18.0	15.0	91.0
Guideline/Reference Level		N/A	240(hour)[i]	160 (one hour)[iii] 125 (8 hour)[ii]

i: Health Canada, 1989 ii: Canada-wide standard, 2010 iii: Alberta's Ambient Air Quality Objectives, 2005

Fort Chipewyan

For Fort Chipewyan, median and 95th percentile concentrations are higher in comparison to the Fort McMurray sample. Higher levels may have been detected as ozone may not be as rapidly destroyed in smaller less industrialized communities such as Fort Chipewyan when compared to Fort McMurray. However, the levels detected in Fort Chipewyan are lower than applicable guidelines.

Table 13: Comparison of O_3 Levels in µg/m^3 with Guidelines – Fort Chipewyan Participants

Parameter	Year	Personal	Indoor	Outdoor
Fort Chipewyan Median	2005	4.2	1.0	82.1
Fort Chipewyan 95th Percentile	2005	19.0	5.0	102.0
Guideline/Reference Level		N/A	240(hour)[i]	160 (one hour)[iii] 125 (8 hour)[ii]

i: Health Canada, 1989 ii: Canada-wide standard, 2010 iii: Alberta's Ambient Air Quality Objectives, 2005

Volatile Organic Compounds

Summary of Results

The analyses of the volatile organic compounds (VOCs) detailed in the following pages share several general features: 1) there were generally many measurements that were below detection limits especially for outdoor monitors (see Table 1); 2) personal exposure levels were generally higher than indoor and outdoor levels; and 3) the strongest relationships occurred between personal and indoor levels of concentration, suggesting indoor sources of exposure for most of these chemicals.

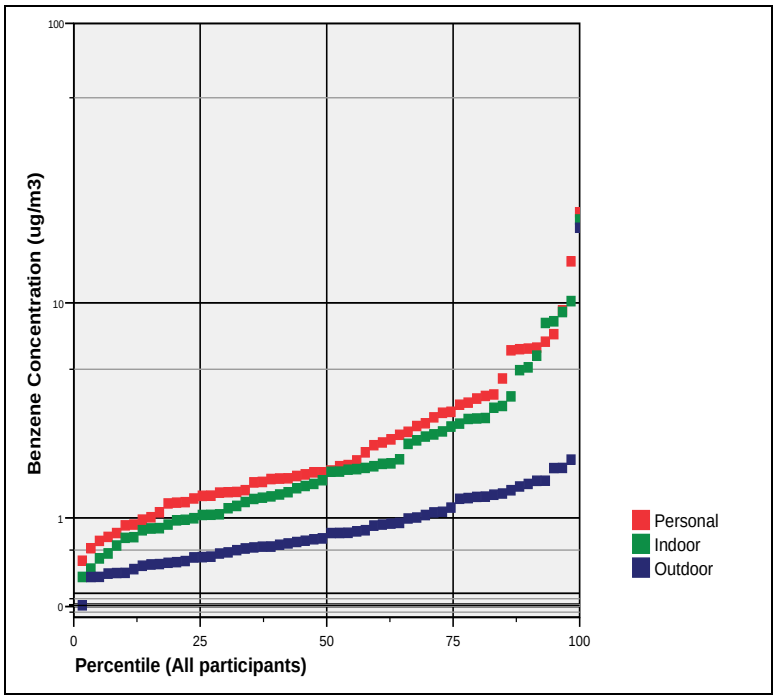
While none of the VOC examined have personal or indoor guidelines levels, three do have ambient (outdoor) air quality objectives as determined by Alberta Environment. These contaminants are benzene, ethylbenzene and toluene. All outdoor monitors for these three contaminants were below their respective objectives.

Benzene

Benzene is found in the combustion of petroleum fuels by motor vehicle engines and emissions associated with many industrial activities including wood processing, coal mining, textile manufacture and processes in the oil and gas industry. Another important source is cigarette smoke which makes a significant contribution to personal exposure. Benzene is a known carcinogen and appears on Health Canada's First Priority Substance List. The MDL of benzene is 0.42 $\mu g/m^3$ with all personal and indoor monitors detecting benzene at higher levels than the detection limit. Only 1.7% of outdoor monitors were below the MDL.

Figure 17 shows the cumulative distribution of benzene concentrations for the three types of samplers (personal, indoor, and outdoor) for all participants. Personal concentration appears to be derived from a cumulative effect of indoor and outdoor concentrations.

Figure 17: Distribution of Benzene – All Participants



Figures 18 and 19 described the distribution of benzene concentrations for each community. The distribution of personal exposure to benzene mimics the distribution pattern of indoor concentrations of benzene in both communities. Outdoor levels of benzene do not appear to be influencing personal exposure to benzene especially in Fort Chipewyan sample.

Figure 18: Distribution of Benzene – Fort McMurray Participants

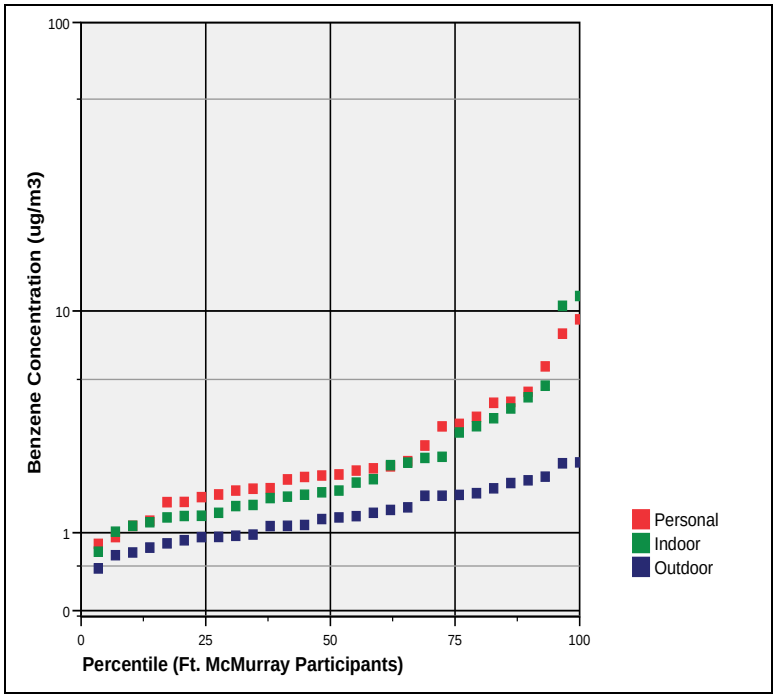
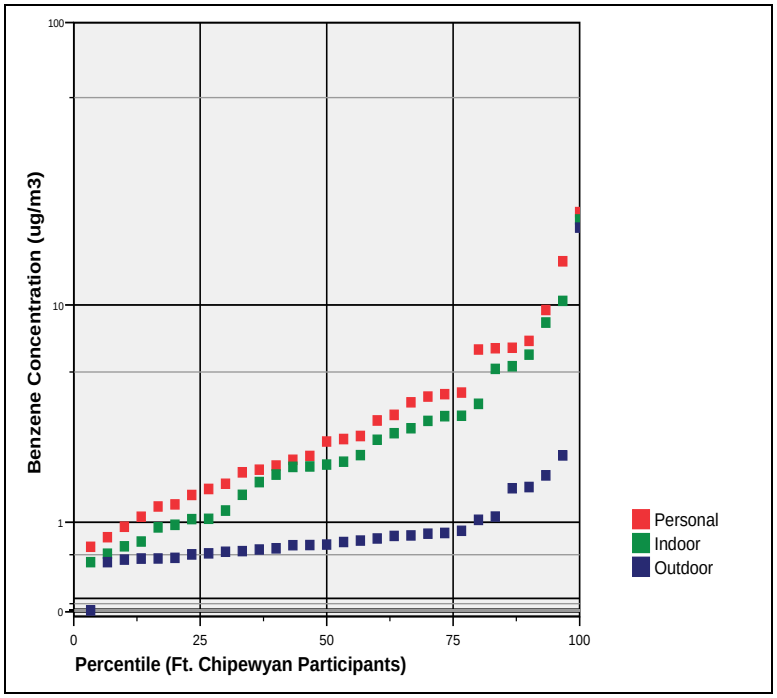


Figure 19: Distribution of Benzene – Fort Chipewyan Participants



For benzene, the following tables describe the median and 95th percentile levels for each location and are compared to applicable guidelines or past programs. For all participants as noted in Table 14, the median and 95th percentile of this contaminant is below acceptable guidelines.

Table 14: Comparison of Benzene Levels in µg/m^3 with Guidelines – All Participants

Parameter	Year	Personal	Indoor	Outdoor
All Participants Median	2005	1.9	1.9	0.8
All Participants 95th Percentile	2005	9.4	9.2	2.0
Relevant Studies		15 (TEAM)[i]	10 (TEAM)[i]	2.6[ii]
Guideline/Reference Level		N/A	N/A	30 (hour)[iii]

i: Wallace, 1996 ii: Dann et al., 1995 iii: Alberta's Ambient Air Quality Objectives, 2005

Fort McMurray

Table 15 provides the monitored levels for the 2000 and 2005 samples taken from the City of Ft. McMurray. The median and 95th percentile concentrations determined from the 2005 Fort McMurray sample in comparison to the 2000 Alberta Oil Sands results were very similar. For both monitoring years, the detected levels were below relevant studies and guideline levels.

Table 15: Comparison of Benzene Levels in µg/m^3 with Guidelines – Fort McMurray Participants

Parameter	Year	Personal	Indoor	Outdoor
Fort McMurray Median	2005	2.1	1.8	1.3
Fort McMurray 95th Percentile	2005	8.8	10.9	2.4
Alberta Oil Sands Median	2000	2.8	1.7	1.3
Alberta Oil Sands 95th Percentile	2000	10.0	6.6	5.5
Relevant Studies		15 (TEAM)[i]	10 (TEAM)[i]	2.6[ii]
Guideline/Reference Level		N/A	N/A	30 (hour)[iii]

i: Wallace, 1996 ii: Dann et al., 1995 iii: Alberta's Ambient Air Quality Objectives, 2005

Fort Chipewyan

The median concentrations for all three samplers in the Fort Chipewyan sample were very similar to those determined in Fort McMurray (Table 16). The US EPA TEAM approach also found that the highest levels of benzene were from the personal samplers, followed by the indoor sampler levels, while the outdoor samplers contained the lowest levels of benzene.[33] In addition, the median outdoor concentrations for both communities monitored in the 2005 year are below the established guideline or reference level.

Table 16: Comparison of Benzene Levels in µg/m^3 with Guidelines – Fort Chipewyan Participants

Parameter	Year	Personal	Indoor	Outdoor
Fort Chipewyan Median	2005	2.8	2.2	0.7
Fort Chipewyan 95th Percentile	2005	17.8	14.9	9.9
Relevant Studies		15 (TEAM)[i]	10 (TEAM)[i]	2.6[ii]
Guideline/Reference Level		N/A	N/A	30 (hour)[iii]

i: Wallace, 1996 ii: Dann et al., 1995 iii: Alberta's Ambient Air Quality Objectives, 2005

Decane

Decane like many hydrocarbons has a gasoline odor, and its vapor which is heavier than air may spread long distances and accumulate in low-lying areas. It is a component of gasoline, jet fuel, and kerosene and is used in the rubber and paper industries. The MDL for decane is 0.64 µg/m^3 with 3.4% of personal monitors and 8.5% of indoor samplers below this limit. The fraction of outdoor samples less than the MDL is high at 79.7%.

Figures 20 and 21 show the distribution of decane concentrations for the three types of samplers (personal, indoor, and outdoor) for each community. Similar to other VOCs, personal exposure concentrations appear to be highly related to indoor exposure concentrations with little to no effect seen from outdoor sources.

Figure 20: Distribution of Decane – Fort McMurray Participants

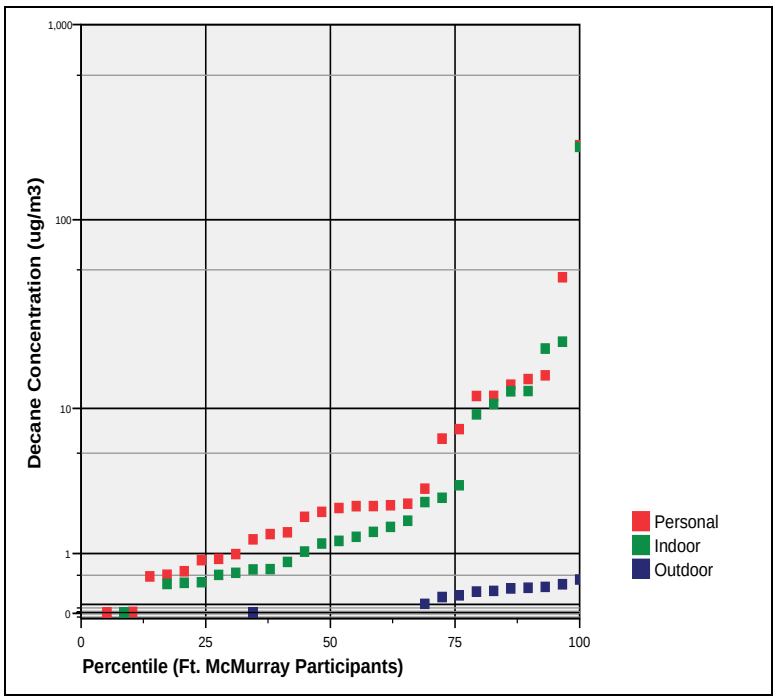


Figure 21: Distribution of Decane – Fort Chipewyan Participants

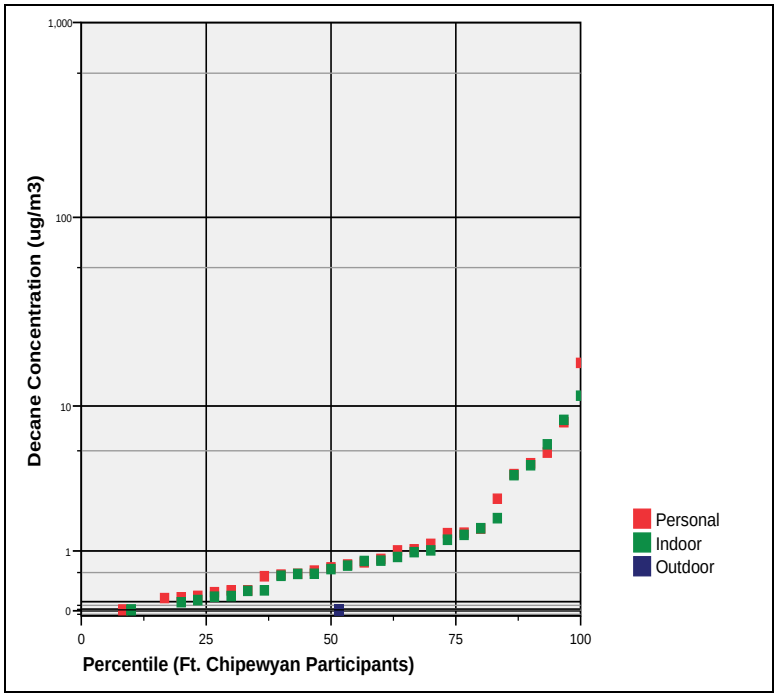


Table 17 is provided to demonstrate the median and 95th percentile concentrations for decane in each type of sampling monitor. Overall, the median personal and indoor concentrations of the Fort McMurray sample are higher than those in Fort Chipewyan. However, as few outdoor monitors detected decane, personal exposure appears to be influenced by personal lifestyle choices or indoor sources.

At this current time there are no Alberta based guideline or reference values for decane for personal, indoor or outdoor exposures.

Table 17: Comparison of Decane Levels in µg/m^3 between Fort McMurray and Fort Chipewyan in the 2005 Monitoring Year

Parameter	Year	Personal	Indoor	Outdoor
Fort McMurray Median	2005	2.4	1.3	0.0
Fort McMurray 95th Percentile	2005	146.1	129.9	0.4
Fort Chipewyan Median	2005	0.8	0.6	0.0
Fort Chipewyan 95th Percentile	2005	12.2	9.7	0.0
Guidelines/Reference Values		N/A	N/A	N/A

Ethylbenzene

Ethylbenzene is used primarily in the production of styrene, a hydrocarbon used to make synthetic rubbers and plastics. It is also a solvent in paints and varnishes, household cleaning products, gasoline, pesticides, carpet glues, asphalt and tobacco smoke. For this analysis, the MDL is 0.55 $\mu g/m^3$ with all personal samplers above the method detection limit. A low percentage (1.7%) of indoor samplers and a moderate percentage of outdoor monitors (64.4%) were below the detection limit.

Figure 22 and 23 shows the cumulative distribution of ethylbenzene concentrations for the three types of samplers (personal, indoor, and outdoor) for each community. Personal exposure appears to be linked to indoor concentrations as can be seen in the distribution for both Fort McMurray and Fort Chipewyan. As a low percentage of outdoor monitors detected ethylbenzene above the MDL, personal exposure does not appear to be affected by outdoor concentrations.

Figure 22: Distribution of Ethylbenzene – Fort McMurray Participants

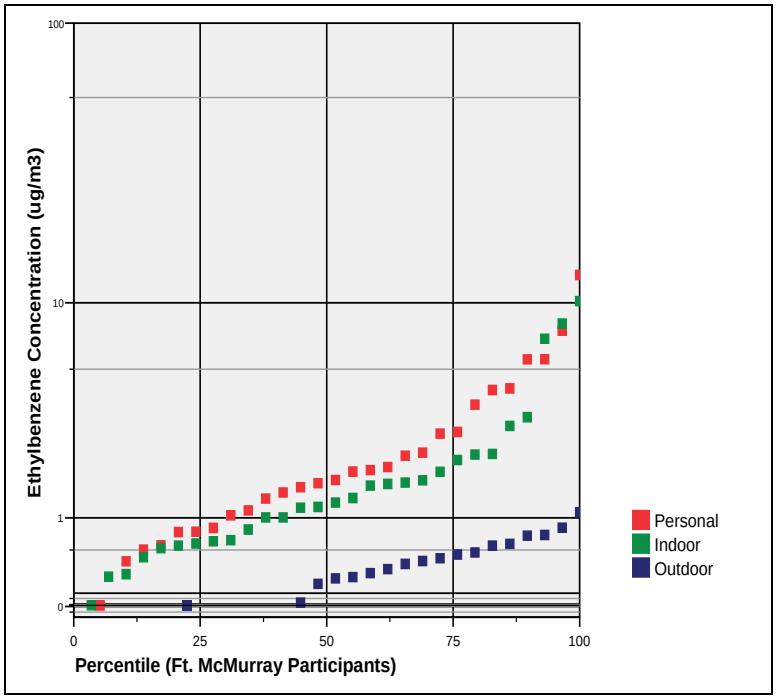


Figure 23: Distribution of Ethylbenzene – Fort Chipewyan Participants

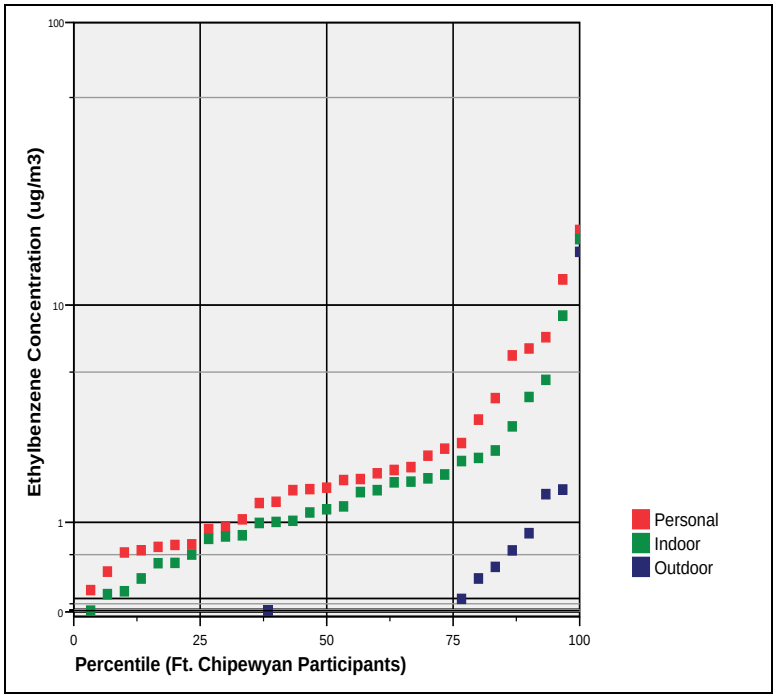


Table 18 is provided to demonstrate the median and 95th percentile concentrations for ethylbenzene in each type of sampling monitor. Overall, the median concentrations for all three sampler sites from each of the monitored communities were the similar. However, as few outdoor monitors detected ethylbenzene personal exposure appears to be influenced by personal lifestyle choices or indoor sources. No monitors exceeded Alberta's Ambient Air Quality Objective for ethylbenzene.

Table 18: Comparison of Ethylbenzene Levels in µg/m^3 between Fort McMurray and Fort Chipewyan in the 2005 Monitoring Year[34]

Parameter	Year	Personal	Indoor	Outdoor
Fort McMurray Median	2005	1.7	1.3	0.2
Fort McMurray 95th Percentile	2005	10.3	9.2	1.0
Fort Chipewyan Median	2005	1.7	1.2	0.0
Fort Chipewyan 95th Percentile	2005	15.3	12.9	7.9
Guidelines/Reference Values		N/A	N/A	2000 (1 hour)[i]

i: Alberta's Ambient Air Quality Objectives, 2005

Heptane

Heptane is colorless and has a gasoline-type odor. Heptane is used as a solvent in glues, varnishes, cements and inks many of which are found in people's homes or work. It is also a major ingredient in gasoline and aviation fuel and in petroleum solvents such as petroleum naphtha and rubber solvent. The MDL of heptane is 0.51µg/m^3 with 18.6% personal and 28.8% indoor monitors detecting concentrations below this limit. Over half of the outdoor monitors (52.5%) reported levels below the MDL.

Figures 24 and 25 show the cumulative distribution of heptane concentrations for the three types of samplers (personal, indoor, and outdoor) in each community. In Fort McMurray, personal and indoor concentrations follow similar trends and were higher than outdoor concentrations. For Fort Chipewyan, the distribution pattern is not as clear due to a fewer number of data points.

Figure 24: Distribution of Heptane – Fort McMurray Participants

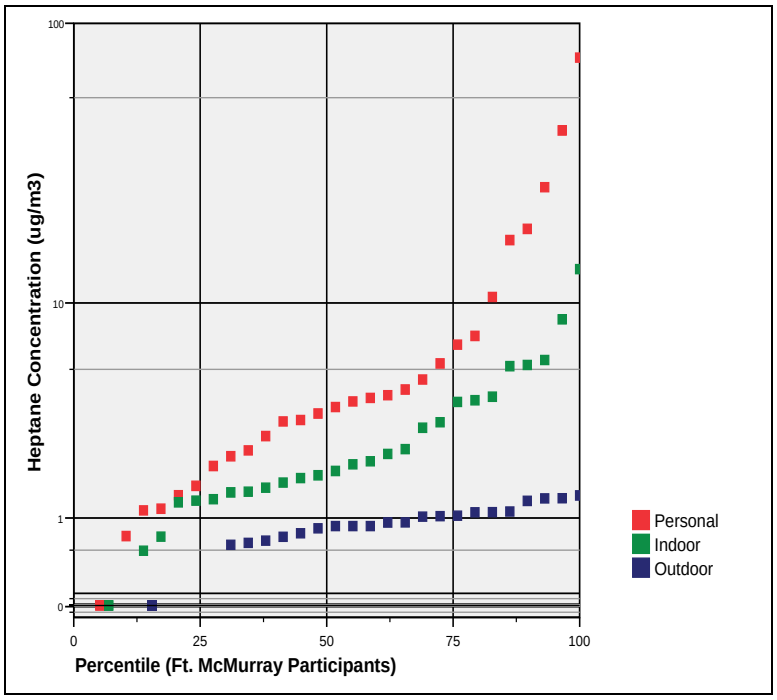


Figure 25: Distribution of Heptane – Fort Chipewyan Participants

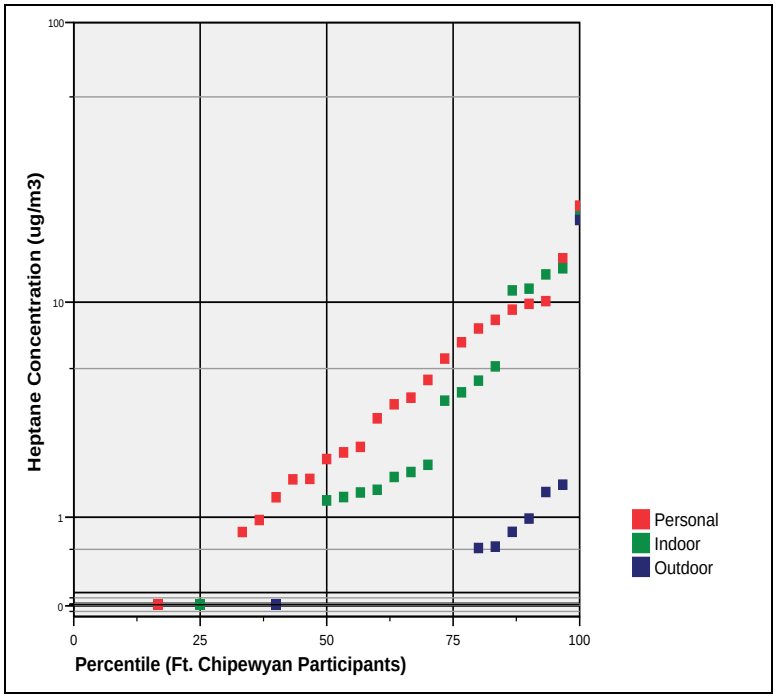


Table 19 is provided to demonstrate the median and 95th percentile concentrations for heptane in each type of sampling monitor. For the 2005 monitoring year, the median concentrations of heptane from each type of sampler were higher in Fort McMurray than in Fort Chipewyan. However, as few outdoor monitors detected heptane especially in Fort Chipewyan, personal exposure appears to be influenced by personal lifestyle choices or indoor sources.

At this current time there are no Alberta guideline or reference values for heptane for personal, indoor or outdoor exposures.

Table 19: Comparison of Heptane Levels in µg/m^3 between Fort McMurray and Fort Chipewyan in the 2005 Monitoring Year

Parameter	Year	Personal	Indoor	Outdoor
Fort McMurray Median	2005	3.8	1.9	0.9
Fort McMurray 95th Percentile	2005	59.1	11.0	1.4
Fort Chipewyan Median	2005	2.3	1.3	0.0
Fort Chipewyan 95th Percentile	2005	18.2	16.7	9.9
Guidelines/Reference Values		N/A	N/A	N/A

Hexane

Hexane is both naturally and synthetically produced and has a mild, gasoline type odour. Found in small amounts in both crude oil and natural gas, it also used in industrial extraction processes. It is also used as a cleaning agent for textiles, furniture and leather so can be expected to be found in indoor environments. The MDL for hexane is 2.2 µg/m^3 and was not detected in 45.8% of personal monitors, 62.7% of indoor monitors, and 98.3% of outdoor monitors.

Figures 26 and 27 show the cumulative distribution of hexane concentrations for the three types of samplers (personal, indoor, and outdoor) for each community. Personal and indoor concentrations in each community follow the same distribution pattern, indicating that personal exposure is related to indoor concentrations.

Figure 26: Distribution of Hexane – Fort McMurray Participants

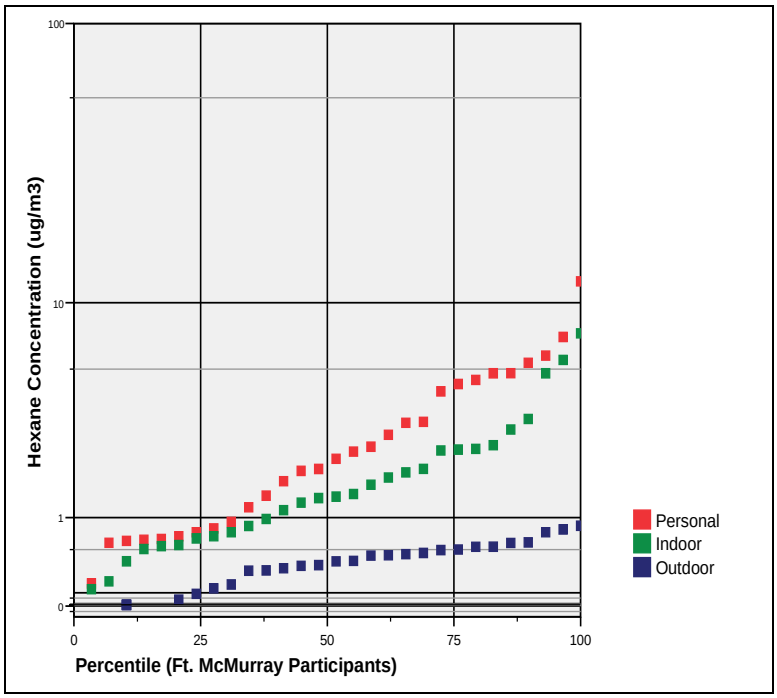


Figure 27: Distribution of Hexane – Fort Chipewyan Participants

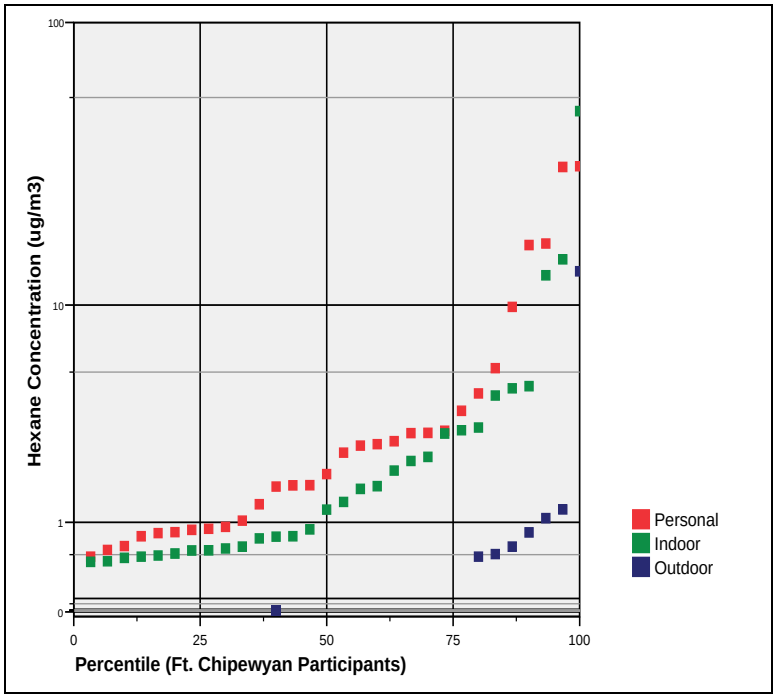


Table 20 is provided to demonstrate the median and 95th percentile concentrations for hexane in each type of sampling monitor. For the 2005 monitoring year, the median concentrations of heptane from each of the monitored communities and sampler types was similar. However, as few outdoor monitors detected hexane especially in Fort Chipewyan, personal exposure appears to be influenced by personal lifestyle choices or indoor sources.

At this current time there are no Alberta guideline or reference values for hexane for personal, indoor or outdoor exposures.

Table 20: Comparison of Hexane Levels in µg/m^3 between Fort McMurray and Fort Chipewyan in the 2005 Monitoring Year

Parameter	Year	Personal	Indoor	Outdoor
Fort McMurray Median	2005	2.2	1.4	0.4
Fort McMurray 95th Percentile	2005	9.7	6.8	0.8
Fort Chipewyan Median	2005	2.2	1.3	0.0
Fort Chipewyan 95th Percentile	2005	31.6	30.3	6.7
Guidelines/Reference Values		N/A	N/A	N/A

Limonene

Limonene is classified chemically as a terpene. Terpenes are produced primarily by plants as an essential oil and usually have a citric or lemon-orange fragrance. In addition to being found as odorants in cleaning products and air fresheners, they are often emitted by wood products and solvents based on pine oil. In industry, limonene is an environmentally friendly alternative to mineral oils as a solvent for cleaning purposes, being more easily biodegradable and produced from a renewable source. The MDL for limonene is 0.50 $\mu g/m^3$ with all personal and indoor monitors determined to above this level. The fraction of outdoor monitors not detecting limonene outdoors was high at 86.4%.

Figures 28 and 29 show the cumulative distribution of limonene concentrations for the three types of samplers (personal, indoor, and outdoor) for each community. Personal and indoor distribution patterns were extremely similar indicating personal exposure is influenced by indoor concentrations.

Figure 28: Distribution of Limonene - Fort McMurray Participants

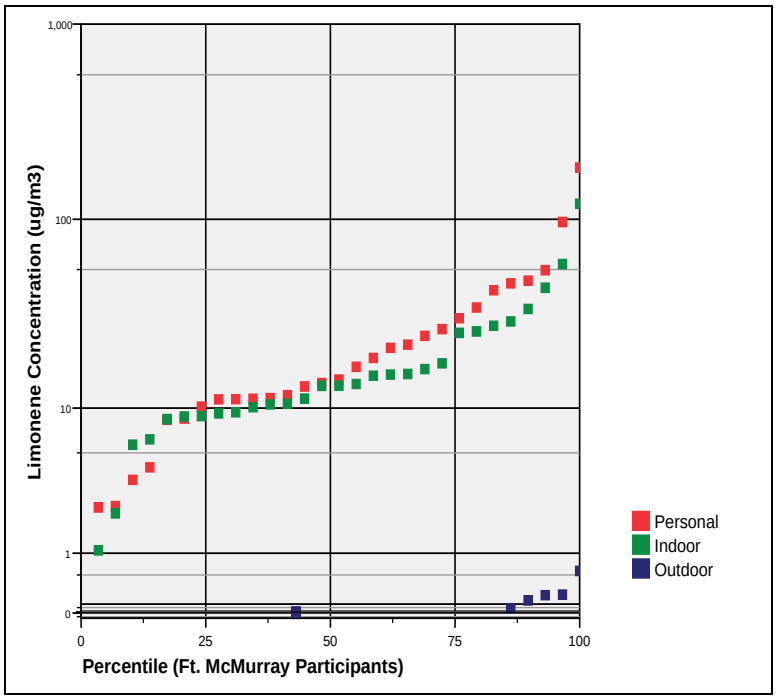


Figure 29: Distribution of Limonene – Fort Chipewyan Participants

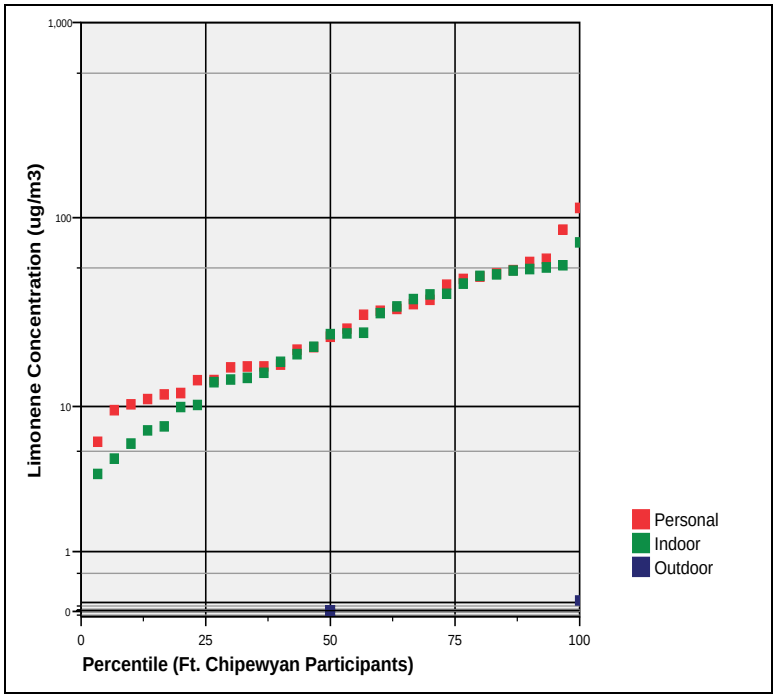


Table 21 is provided to demonstrate the median and 95th percentile concentrations for limonene in each type of sampling monitor. For the 2005 monitoring year, the median personal and indoor concentrations of limonene was higher in the Fort Chipewyan than in Fort McMurray. In addition, the median concentrations were similar suggesting that personal exposure is influenced on indoor sources. As few outdoor monitors detected limonene, outdoor sources do not appear to have an effect on personal exposure.

At this current time there are no Alberta guideline or reference values for limonene for personal, indoor or outdoor exposures.

Table 21: Comparison of Limonene Levels in µg/m^3 between Fort McMurray and Fort Chipewyan in the 2005 Monitoring Year

Parameter	Year	Personal	Indoor	Outdoor
Fort McMurray Median	2005	14.4	13.2	0.0
Fort McMurray 95th Percentile	2005	140.6	89.5	0.4
Fort Chipewyan Median	2005	25.2	24.8	0.0
Fort Chipewyan 95th Percentile	2005	98.3	64.8	0.1
Guidelines/Reference Values		N/A	N/A	N/A

3-Methylhexane

Methylhexane is an isomer of heptane, which means it has the same chemical formula as heptane but the atoms in the molecule are arranged differently. Methylhexane is colourless with a gasoline like odour and is commonly found in paint and solvents. The MDL for 3-methylhexane is 0.51 µg/m^3 and in the exposure monitors deployed 6.8% of personal, 13.6% of indoor, and 55.9% of outdoor samplers were below the detection limit.

Figures 30 and 31 show the cumulative distribution of *3*-methylhexane concentrations for the three types of samplers (personal, indoor, and outdoor) for each community. For Fort McMurray, personal and indoor concentrations once again followed similar distributions, with little influence from outdoor sources. This was also seen in the Fort Chipewyan sample.

Figure 30: Distribution of *3*–Methylhexane - Fort McMurray Participants

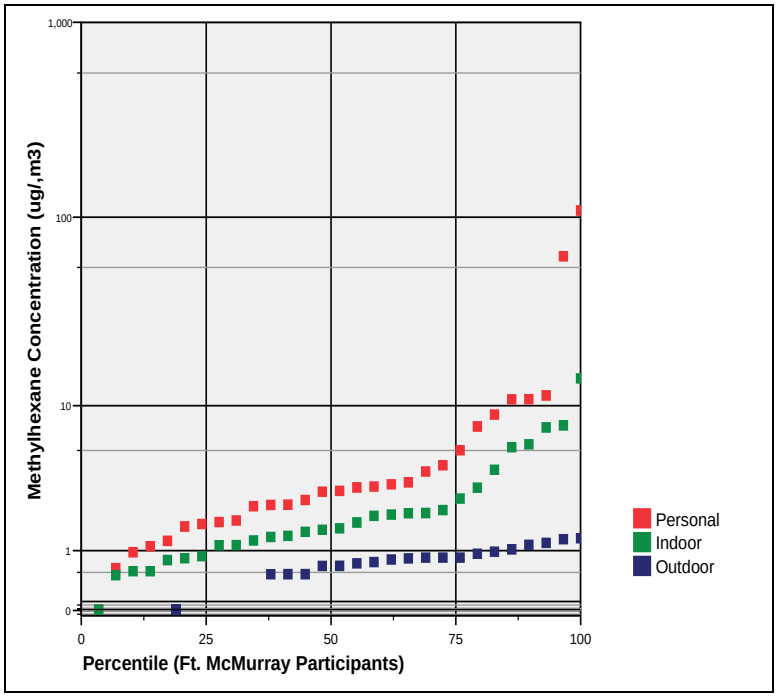


Figure 31: Distribution of *3*–Methylhexane - Fort Chipewyan Participants

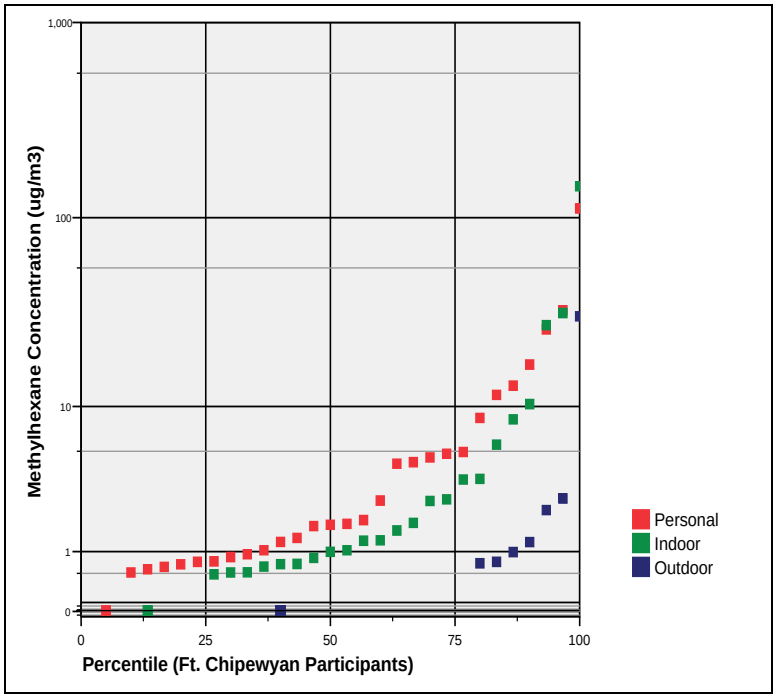


Table 22 is provided to demonstrate the median and 95th percentile concentrations for *3*-methylhexane in each type of sampling monitor. For the 2005 monitoring year, the median concentrations for each sampler type were higher in Fort McMurray than in Fort Chipewyan. As few outdoor monitors detected *3*-methylhexane especially in Fort Chipewyan, outdoor sources do not appear to have an effect on personal exposure.

At this current time there are no Alberta guideline or reference values for *3*-methylhexane for personal, indoor or outdoor exposures.

Table 22: Comparison of *3*-Methylhexane Levels in µg/m^3 between Fort McMurray and Fort Chipewyan in the 2005 Monitoring Year

Parameter	Year	Personal	Indoor	Outdoor
Fort McMurray Median	2005	3.0	1.6	0.7
Fort McMurray 95th Percentile	2005	85.6	10.9	1.3
Fort Chipewyan Median	2005	1.8	1.0	0.0
Fort Chipewyan 95th Percentile	2005	68.4	82.9	15.3
Guidelines/Reference Values		N/A	N/A	N/A

m-, p-Xylene

Major environmental releases of xylene are due to emissions from petroleum refining, chemical plants and automobile exhaust. Xylenes are also found in a variety of consumer products including gasoline, paint, paint thinners and cigarette smoke. The MDL for *m-, p*-xylene is 1.0 µg/m^3 with 1.7%% of personal and 1.7% of indoor monitors less than this detection limit. The outdoor fraction of samples below the MDL is 32.2%.

Figures 32 and 33 show the cumulative distribution of *m-, p*-xylene concentrations for the three types of samplers (personal, indoor, and outdoor) for each community. For each sample, personal exposure appears to be strongly related to indoor concentrations, with outdoor concentrations having no or a very low effect.

Figure 32: Distribution of *m-, p*–Xylene – Fort McMurray Participants

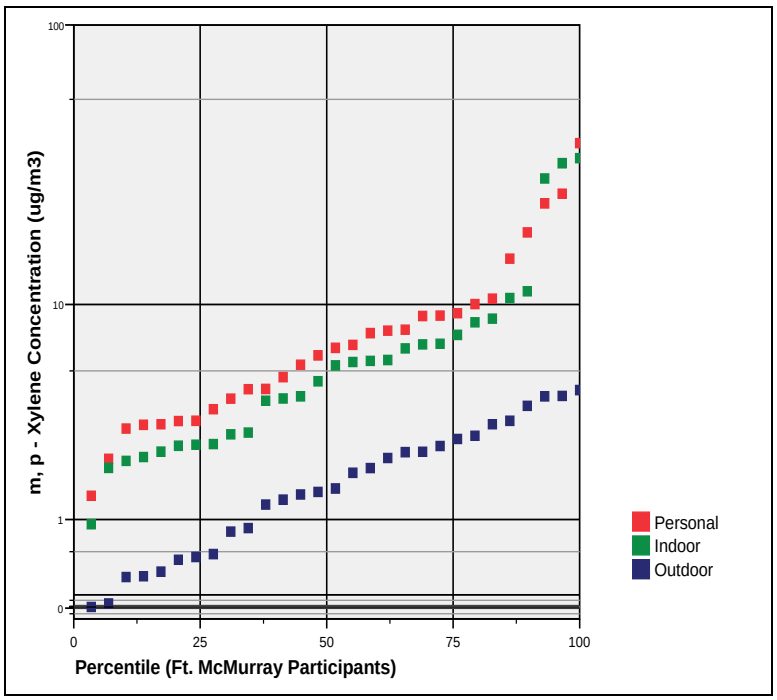


Figure 33: Distribution of *m-, p*–Xylene – Fort Chipewyan Participants

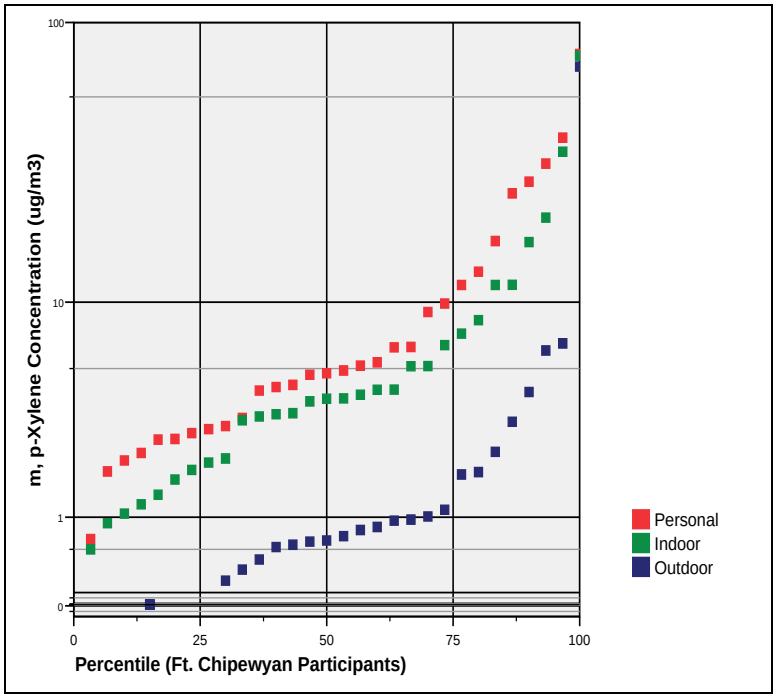


Table 23 is provided to demonstrate the median and 95th percentile concentrations for *m-, p* – xylene in each type of sampling monitor. For the 2005 monitoring year, the median concentrations for each sampler type were slightly higher in Fort McMurray than in Fort Chipewyan. As indoor median concentrations are similar to median personal concentrations, indoor sources of this VOC appear to be contributing to personal exposure.

At this current time there are no Alberta guideline or reference values for *m-, p*-xylene for personal, indoor or outdoor exposures.

Table 23: Comparison of *m-, p*-xylene Levels in µg/m^3 between Fort McMurray and Fort Chipewyan in the 2005 Monitoring Year

Parameter	Year	Personal	Indoor	Outdoor
Fort McMurray Median	2005	6.8	5.8	1.6
Fort McMurray 95th Percentile	2005	32.0	33.4	4.5
Fort Chipewyan Median	2005	5.3	4.1	0.7
Fort Chipewyan 95th Percentile	2005	56.7	53.9	35.4
Guidelines/Reference Values		N/A	N/A	N/A

N- propylbenzene

N-propylbenzene is found naturally in petroleum and bituminous coal but is released to the atmosphere in emissions from combustion sources such as incinerators, gasoline and diesel engines. It is also found in building and construction insulation, floor and wall covering, scatter rugs, bathmats and wood office work surfaces. The MDL is 0.60 µg/m^3 with 32.2% of personal, 47.5% of indoor and 93.2% of outdoor monitors below this detection limit.

Figures 34 and 35 show the cumulative distribution of *N*-propylbenzene concentrations for the three types of samplers (personal, indoor, and outdoor) for each sample group. Despite the low fraction of monitors detecting this VOC, the distribution of personal and indoor concentrations follow similar trends indicating personal exposure may be related to indoor concentrations.

Figure 34: Distribution of *N*–propylbenzene – Fort McMurray Participants

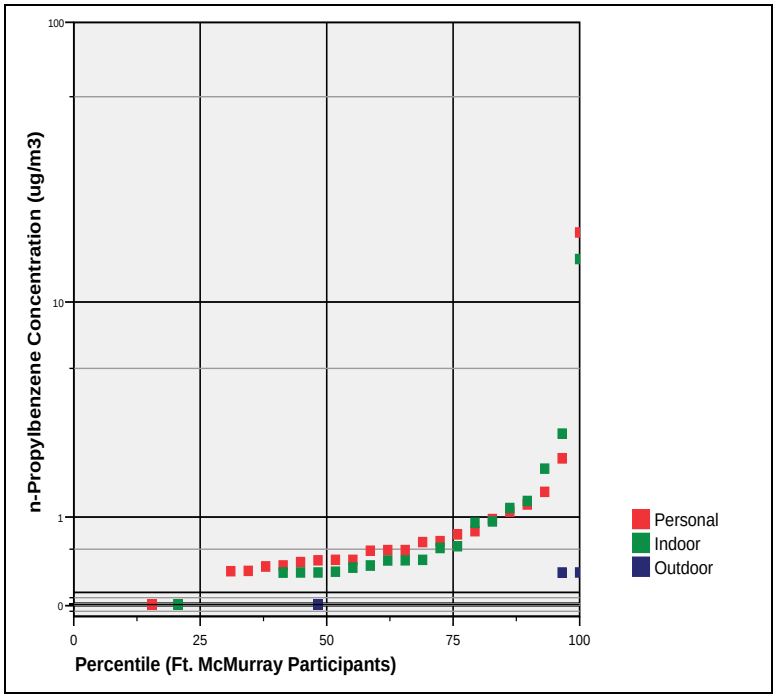


Figure 35: Distribution of *N* - propylbenzene – Fort Chipewyan Participants

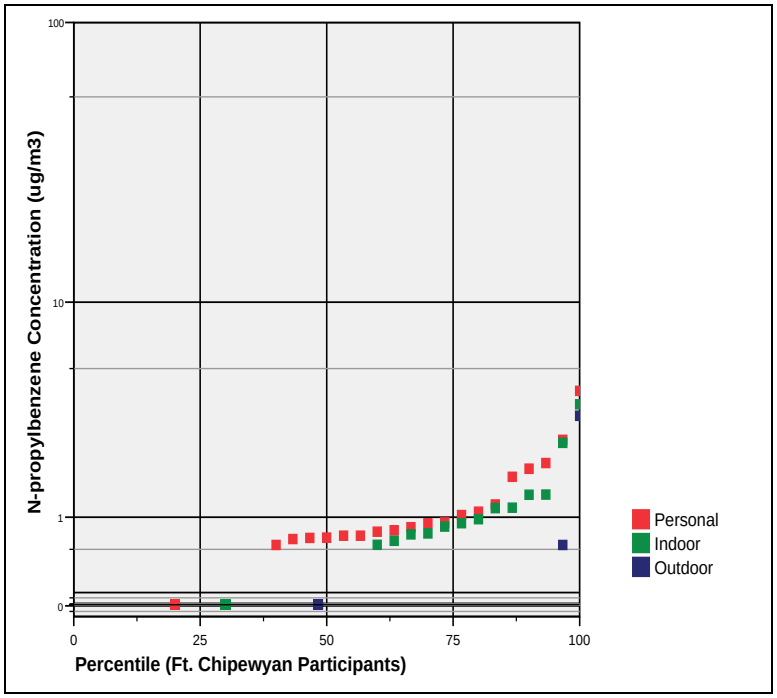


Table 24 is provided to demonstrate the median and 95th percentile concentrations for *N*–propylbenzene in each type of sampling monitor. For the 2005 monitoring year, the median personal and indoor concentrations from each monitored community were similar. As a low proportion of outdoor monitors detected *N*-propylbenzene, outdoor sources of this contaminant do not appear to influence personal exposure.

At this current time there are no Alberta guideline or reference values for *N*–propylbenzene for personal, indoor or outdoor exposures.

Table 24: Comparison of *N*-propylbenzene Levels in µg/m^3 between Fort McMurray and Fort Chipewyan in the 2005 Monitoring Year

Parameter	Year	Personal	Indoor	Outdoor
Fort McMurray Median	2005	0.4	0.3	0.0
Fort McMurray 95th Percentile	2005	10.1	8.7	0.3
Fort Chipewyan Median	2005	0.7	0.0	0.0
Fort Chipewyan 95th Percentile	2005	3.5	3.2	1.9
Guidelines/Reference Values		N/A	N/A	N/A

Nonane

Nonane is colorless and is an important component of gasoline and petroleum solvents. It is also used in the manufacture of paraffin products, paper processing and rubber industry and synthesis of biodegradable detergents. The MDL for nonane is 0.60 µg/m^3 with a high fraction of all samples less than this limit. The proportions were as follows: 13.6% for personal, 37.3% for indoor and 94.9% for outdoor.

Figures 36 and 37 show the cumulative distribution of nonane concentrations for the three types of samplers (personal, indoor, and outdoor) for each community. Personal concentrations were slightly higher than indoor concentrations suggesting the correlation between an indoor and personal source. Very few outdoor samplers recorded detectable nonane.

Figure 36: Distribution of Nonane – Fort McMurray Participants

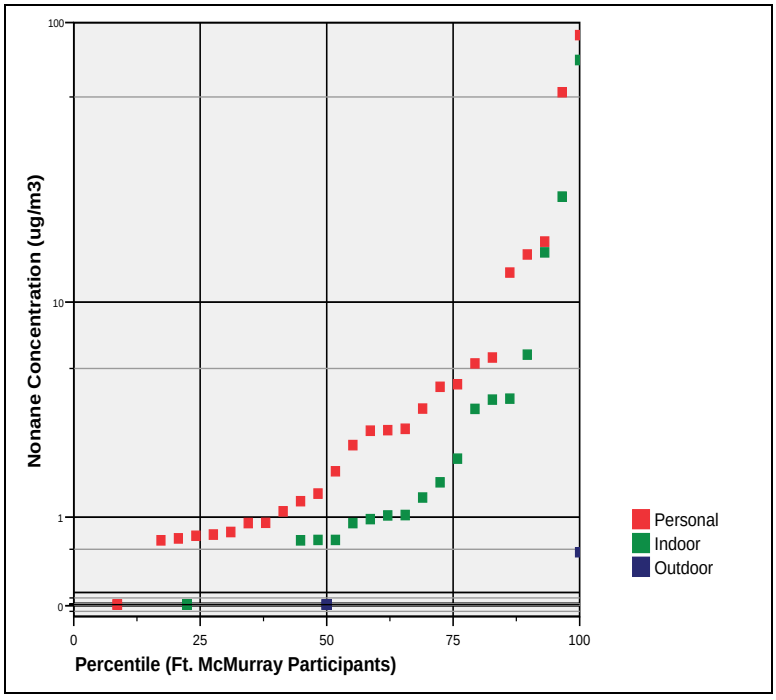


Figure 37: Distribution of Nonane – Fort Chipewyan Participants

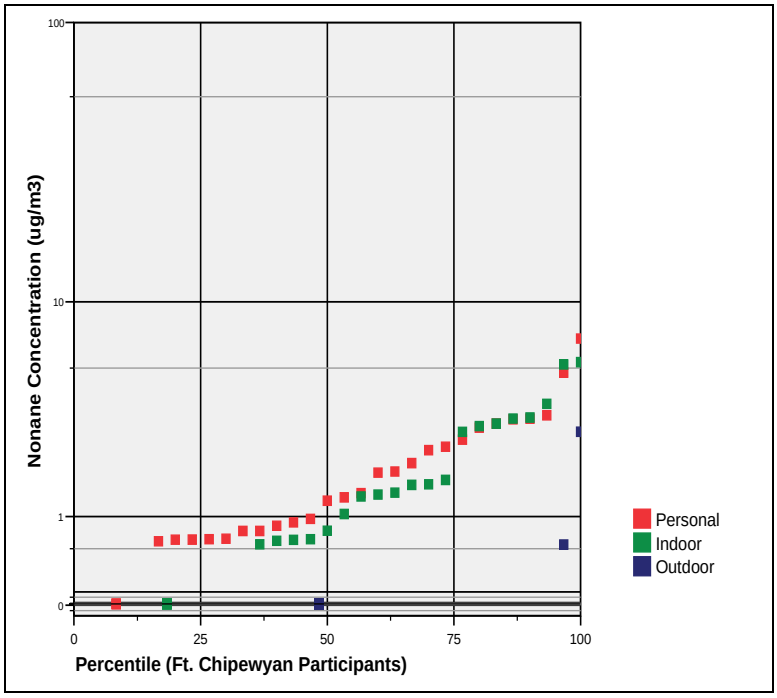


Table 25 is provided to demonstrate the median and 95th percentile concentrations for nonane in each type of sampling monitor. For the 2005 monitoring year, the median personal and indoor concentrations from each monitored community were similar. In addition, the median personal and indoor concentrations within each sample group are similar indicating indoor sources influence personal exposure. As a low proportion of outdoor monitors detected nonane, outdoor sources of this contaminant do not appear to influence personal exposure.

At this current time there are no Alberta guideline or reference values for nonane for personal, indoor or outdoor exposures.

Table 25: Comparison of Nonane Levels in µg/m^3 between Fort McMurray and Fort Chipewyan in the 2005 Monitoring Year

Parameter	Year	Personal	Indoor	Outdoor
Fort McMurray Median	2005	1.8	0.7	0.0
Fort McMurray 95th Percentile	2005	73.8	49.2	0.3
Fort Chipewyan Median	2005	1.3	0.9	0.0
Fort Chipewyan 95th Percentile	2005	6.1	5.7	1.6
Guidelines/Reference Values		N/A	N/A	N/A

Octane

Octane is a well known component of gasoline but other sources include aerosol paint concentrates, eye preparations (mascara, eye shadow), furniture polish and cleaners. It is also found in all types of paint and paint thinners, wood office furniture, photocopying machines and work surfaces (modular systems). The MDL for is 0.56 µg/m^3 with 5.1% of personal and 5.1% of indoor below this limit. A high percentage (66.1%) of the outdoor monitors was below the MDL.

Figures 38 and 39 show the cumulative distribution of octane concentrations for the three types of samplers (personal, indoor, and outdoor) of each sample group. Especially for Fort Chipewyan, personal and indoor levels follow a similar distribution inferring personal exposure is related to indoor sources. The pattern was similar in the Fort McMurray sample but not as strong. Outdoor concentrations do not appear to be having an effect on personal exposure in either community.

Figure 38: Distribution of Octane – Fort McMurray Participants

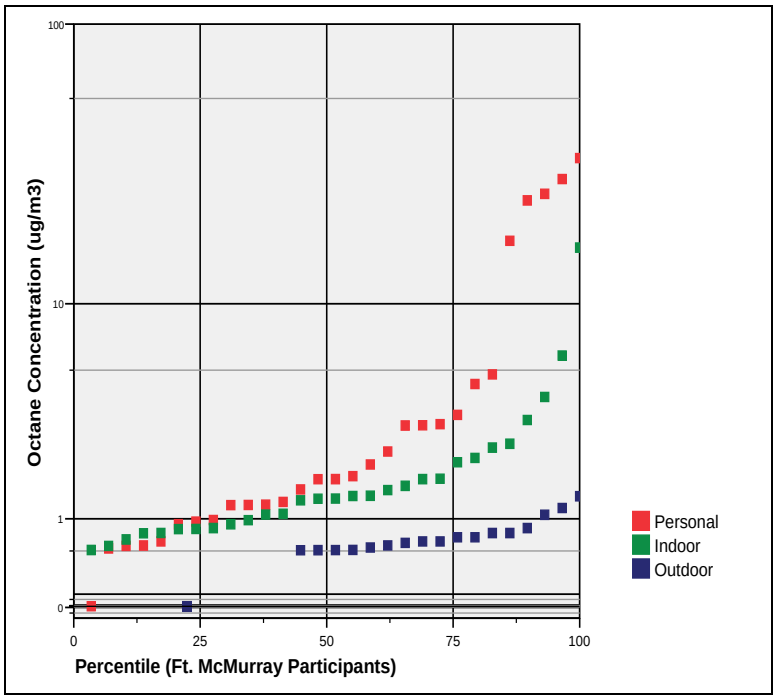


Figure 39: Distribution of Octane – Fort Chipewyan Participants

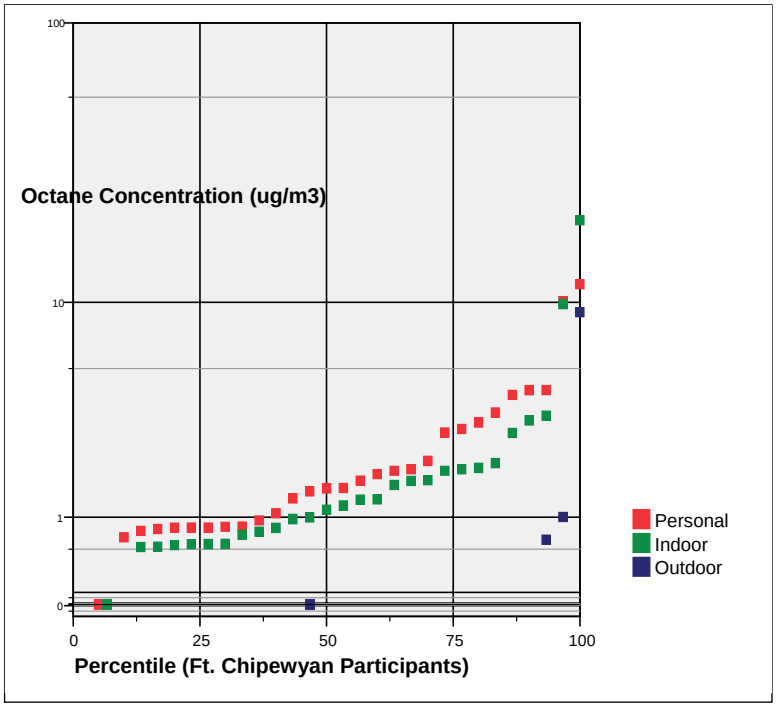


Table 26 is provided to demonstrate the median and 95th percentile concentrations for octane in each type of sampling monitor. For the 2005 monitoring year, the median personal and indoor concentrations from each monitored community were similar. In addition, the median personal and indoor concentrations within each sample group are similar indicating indoor sources influence personal exposure. As a low proportion of outdoor monitors detected octane, outdoor sources of this contaminant do not appear to influence personal exposure.

At this current time there are no Alberta guideline or reference values for octane for personal, indoor or outdoor exposures.

Table 26: Comparison of Octane Levels in µg/m^3 between Fort McMurray and Fort Chipewyan in the 2005 Monitoring Year

Parameter	Year	Personal	Indoor	Outdoor
Fort McMurray Median	2005	1.7	1.3	0.6
Fort McMurray 95th Percentile	2005	31.2	11.2	1.3
Fort Chipewyan Median	2005	1.5	1.2	0.0
Fort Chipewyan 95th Percentile	2005	10.8	14.5	4.7
Guidelines/Reference Values		N/A	N/A	N/A

o–Xylene

This second type of xylene is found in the same environmental releases as *m-, p*-xylene such as petroleum refining, chemical plants, automobile exhaust and as a solvent. Likewise, it is found in a variety of consumer products including gasoline, paint, paint thinners and removers, rust preventatives and cigarette smoke. Any type of xylene appears on Health Canada's First Priority Substance List. The MDL for *o*-xylene is 0.55 µg/m^3 with 1.7% of personal and 5.1% of indoor monitors less than this level. A moderate fraction of the outdoor monitors, 45.8% were less than the MDL.

Figures 40 and 41 show the cumulative distribution of *o*-xylene concentrations for the three types of samplers (personal, indoor, and outdoor). Like other VOCs previously shown, personal and indoor distribution patterns are very similar, particularly for Fort McMurray. While an outdoor source is present, it does not appear to be influencing personal exposure.

Figure 40: Distribution of *o*-Xylene - Fort McMurray Participants

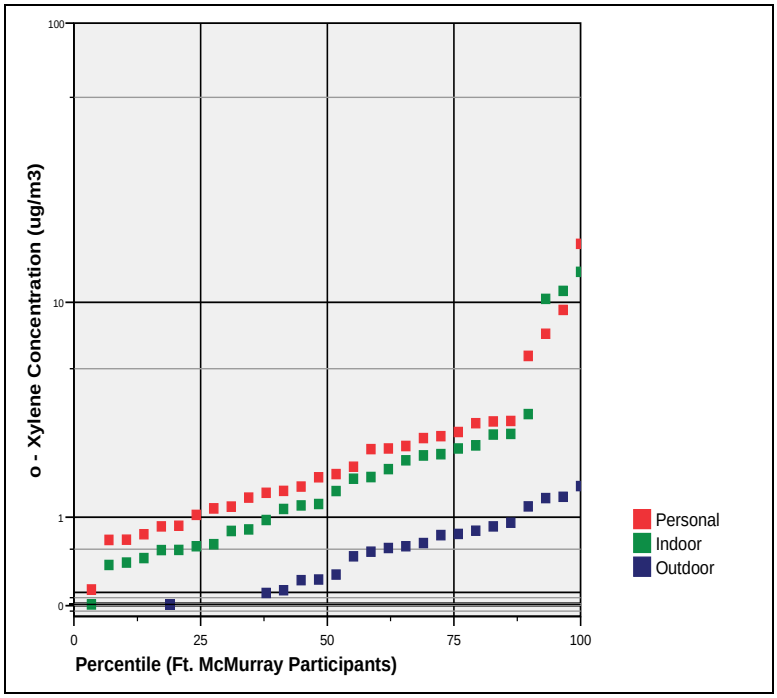


Figure 41: Distribution of *o*–Xylene – Fort Chipewyan Participants

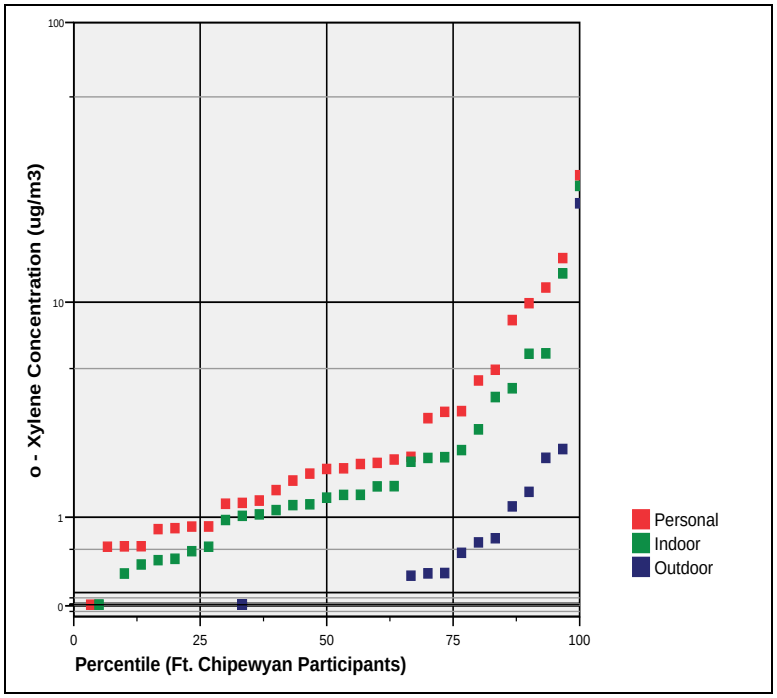


Table 27 is provided to demonstrate the median and 95th percentile concentrations for *o*-xylene in each type of sampling monitor. For the 2005 monitoring year, the median personal and indoor concentrations from each monitored community were similar. In addition, the median personal and indoor concentrations within each sample group are similar indicating indoor sources influence personal exposure. As a low proportion of outdoor monitors detected *o*–xylene, outdoor sources of this contaminant do not appear to influence personal exposure.

At this current time there are no Alberta guideline or reference values for *o*–xylene for personal, indoor or outdoor exposures.

Table 27: Comparison of *o*–Xylene Levels in µg/m^3 between Fort McMurray and Fort Chipewyan in the 2005 Monitoring Year

Parameter	Year	Personal	Indoor	Outdoor
Fort McMurray Median	2005	1.8	1.5	0.3
Fort McMurray 95th Percentile	2005	12.9	12.0	1.5
Fort Chipewyan Median	2005	1.9	1.4	0.0
Fort Chipewyan 95th Percentile	2005	21.1	19.0	11.8
Guidelines/Reference Values		N/A	N/A	N/A

Toluene

Toluene is used in the production of benzene and urethane and is also a gasoline additive. It is also used in the manufacture of explosives, dyes, cements, spot removers, cosmetics, antifreeze, asphalt and detergent. Like benzene, toluene also appears on Health Canada's First Priority Substances List. The MDL of toluene is 2.6 $\mu g/m^3$ with all personal monitors detecting toluene and 1.7% of indoor monitors below this limit. Approximately two-thirds, or 66.4% of the outdoor monitors had readings less than the MDL.

Figures 42 and 43 show the cumulative distribution of toluene concentrations for the three types of samplers (personal, indoor, and outdoor) for each sample group. For both communities, at the 50th percentile, personal and indoor concentrations are over an order of magnitude higher than outdoor concentrations and follow a similar distribution pattern. As a result, outdoor levels have little to no influence on personal exposure. This graph therefore identifies that personal exposure to toluene is associated with indoor levels in our homes.

Figure 42: Distribution of Toluene – Fort McMurray Participants

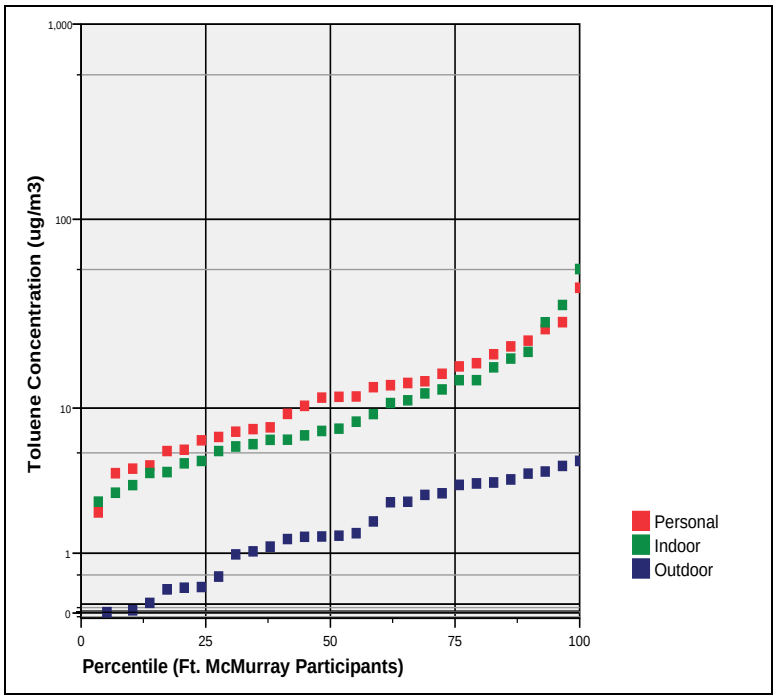


Figure 43: Distribution of Toluene – Fort Chipewyan Participants

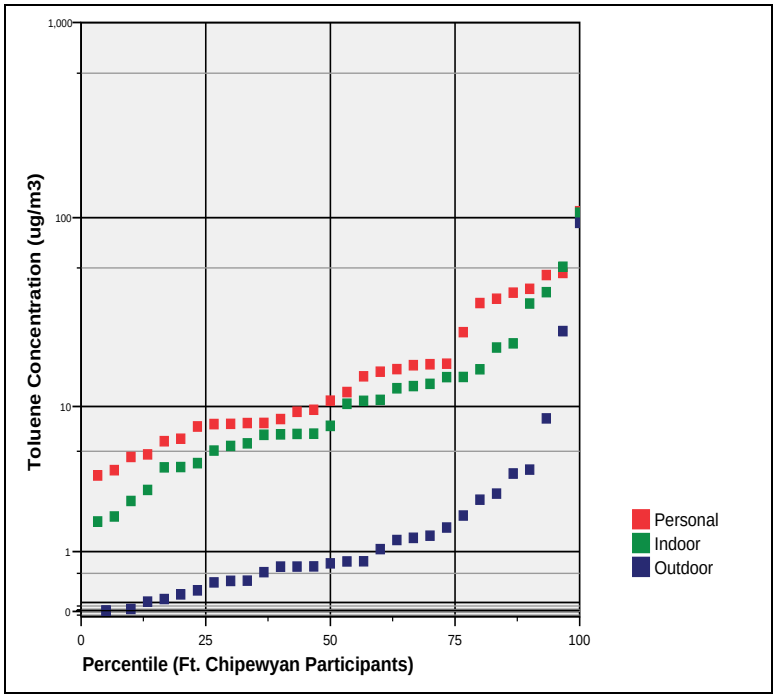


Table 28 is provided to demonstrate the median and 95th percentile concentrations for toluene in each type of sampling monitor. For the 2005 monitoring year, the median personal and indoor concentrations from each monitored community were similar. Indoor sources appear to affect the level of personal exposure to toluene, with outdoor sources having a limited effect. Also, it should be noted the outdoor concentrations detected around the participant's home are lower than Alberta's Ambient Air Quality Objectives.

Table 28: Comparison of Toluene Levels in µg/m^3 between Fort McMurray and Fort Chipewyan in the 2005 Monitoring Year[43]

Parameter	Year	Personal	Indoor	Outdoor
Fort McMurray Median	2005	11.6	7.6	1.5
Fort McMurray 95th Percentile	2005	36.7	45.7	4.7
Fort Chipewyan Median	2005	11.4	9.1	0.8
Fort Chipewyan 95th Percentile	2005	77.1	78.4	56.5
Guidelines/Reference Values		N/A	N/A	1880 (one hour)[i] 400 (24 hour)[i]

i: Alberta's Ambient Air Quality Objectives, 2005

2.2 Particulate Samplers

Particulate matter (PM) samples were also collected from selected participants in both Fort McMurray and Fort Chipewyan. To determine exposure to particulate matter, air is actively collected or drawn by a pump onto a filter which is submitted for laboratory analysis. As with the passive exposure monitors (PEMs), the particulate filters were deployed inside and outside the households, and operate in the area of the individual's breathing zone, and blanks were also completed for quality assurance and control purposes. Particulate matter samples were all of the $PM_{2.5}$ range (smaller air-borne particles less than 2.5µm in size) which can penetrate lung tissue. As with the PEMs, all samples were deployed for a consecutive 7-day period.

From each sample it was possible to determine the concentration of particles in the air. Each sample was also analyzed for a variety of metals. Table 29 shows the metals that were analyzed.

Table 29: Metals Analyzed from Particulate Samples

Standard Chemical Abbreviation	Chemical Name	Standard Chemical Abbreviation	Chemical Name
AG	Silver	MN	Manganese
AL	Aluminum	MO	Molybdenum
AS	Arsenic	NA	Sodium
B	Boron	NI	Nickel
BA	Barium	P	Phosphorus
BE	Beryllium	PB	Lead
BI	Bismuth	S	Sulfur
CA	Calcium	SB	Antimony
CD	Cadmium	SE	Selenium
CL	Chlorine	SI	Silicon
CO	Cobalt	SN	Tin
CR	Chromium	SR	Strontium
CU	Copper	TH	Thorium
FE	Iron	TI	Titanium
HG	Mercury	TL	Thallium
K	Potassium	U	Uranium
LI	Lithium	V	Vanadium
MG	Magnesium	ZN	Zinc

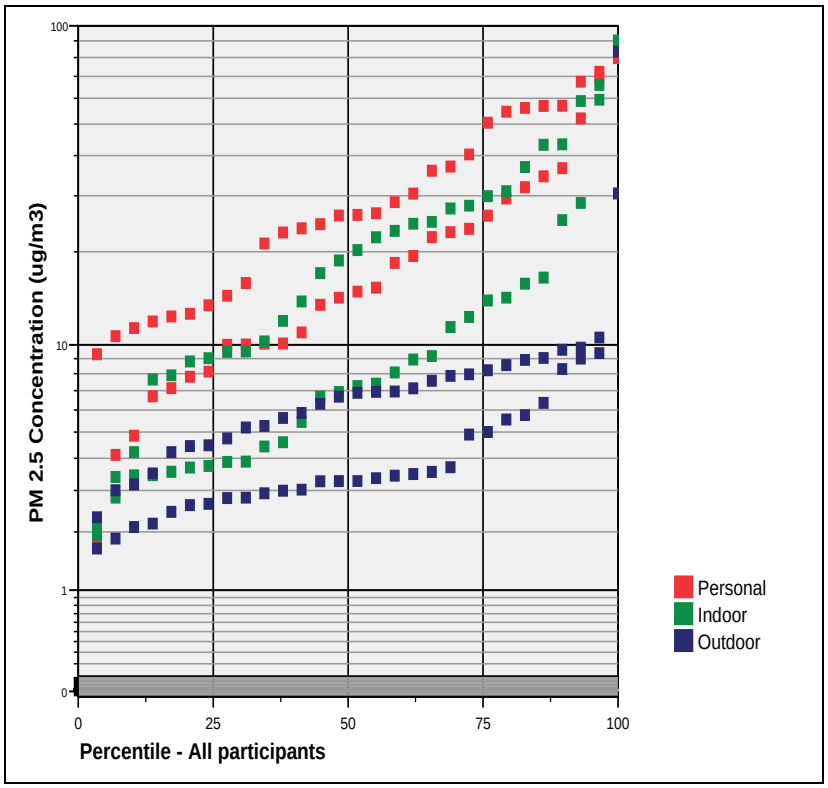
A total of 59 participants wore the particulate monitors and had them placed inside and outside their homes. One additional particulate matter filter was deployed for a personal and outdoor location to replace ones that were damaged. Table 30 shows the distribution of the 201 particulate matter filters.

Table 30: Distribution of Particulate Matter ($PM_{2.5}$) Filters

Location	Totals
Personal	60
Indoor	59
Outdoor	60
Blank	22
Total	201

Figure 44 shows the cumulative distribution of $PM_{2.5}$ concentrations for the three types of samplers for the 2005 Monitoring Year. The distribution pattern shown in this figure is unique and demonstrates that two separate samples are being described. To understand influences of personal exposure for each community, the samples need to be separated as in Figures 44 and 45.

Figure 44: Distribution of Particulate Matter ($PM_{2.5}$) – All Participants



Figures 45 and 46 show the distribution of $PM_{2.5}$ concentrations for Fort McMurray and Fort Chipewyan. For Fort McMurray (Figure 45), indoor and outdoor concentrations have similar distributions which are lower than personal exposure. For Fort Chipewyan (Figure 46), personal and indoor concentrations have a similar pattern indicating a relationship between personal and indoor exposure. Outdoor concentrations are lower indicating a lower influence on personal exposure.

Figure 45: Distribution of Particulate Matter ($PM_{2.5}$) – Fort McMurray Participants

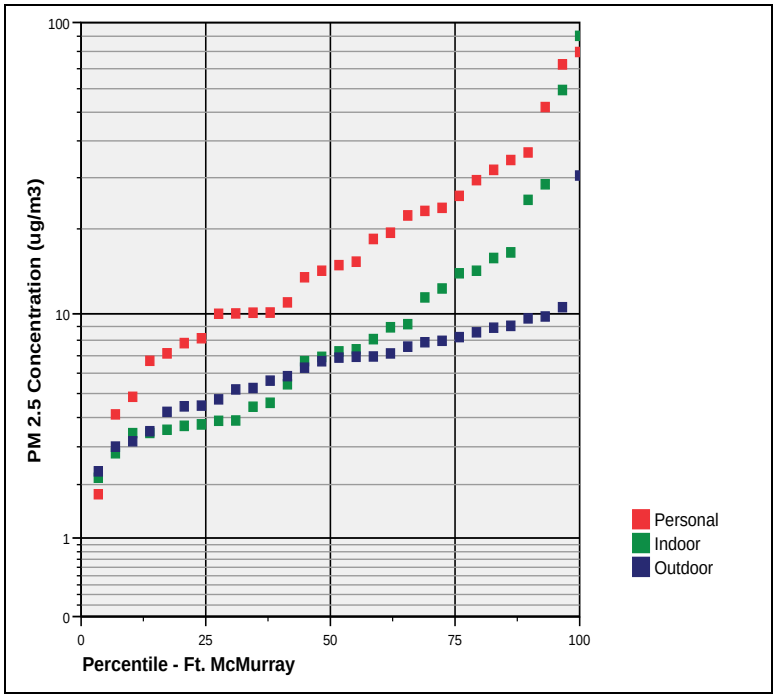
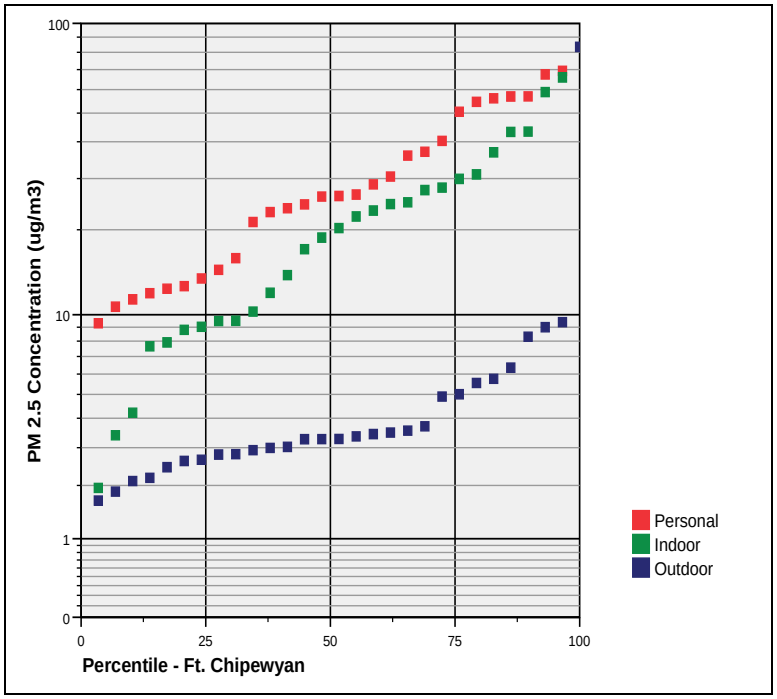


Figure 46: Distribution of Particulate Matter ($PM_{2.5}$) – Fort Chipewyan Participants



The median and 95th percentile $PM_{2.5}$ levels for the different locations are summarized in Table 31 and compared to guidelines and levels in other communities. In addition, the 2000 Alberta Oil Sands Program results are provided in this table. The ambient $PM_{2.5}$ guideline is currently under review and will be replaced by a Canadian wide standard of 30µg/m^3 over a 24-hour period by 2010.[35]

The median level from all three samplers from the 2005 Fort McMurray sample are lower than previously measured in the 2000 Alberta Oil Sands studies. As the personal and indoor medians are not closely related, personal exposure appears to be influenced by other factors such as lifestyle choices (i.e. smoking) or occupation. In comparison, the 2005 Fort Chipewyan personal and indoor median concentrations are higher than those measured in the 2005 Fort McMurray sample. However, as the median outdoor concentration for Fort Chipewyan is lower than in Fort McMurray, personal activities or indoor levels may be primary influences to personal exposure.

Table 31: Comparison of Particulate Matter ($PM_{2.5}$) Levels in µg/m^3 with Guidelines and Other Studies

Parameter	Year	Personal	Indoor	Outdoor
Fort McMurray Median	2005	14.9	7.3	6.9
Fort McMurray 95th Percentile	2005	75.9	74.8	20.5
Fort Chipewyan Median	2005	26.1	20.3	3.3
Fort Chipewyan 95th Percentile	2005	93.8	86.4	46.4
Alberta Oil Sands Median	2000	25.0	8.6	8.4
Alberta Oil Sands 95th Percentile	2000	88	3.5	23.2
Guideline/Reference Level		N/A	40 long term[i] 100 (hour)[i]	30[ii]

**due to the separate distribution patterns evident in Figure 43 these numbers are not provided.*

i: Health Canada, 1989

ii: Canada Wide Standard, 2010

3.0 Conclusions

The goal of the Wood Buffalo Environmental Association's Human Exposure Monitoring Program is to determine and explore the relationship between air quality and human health outcomes. This program while limited in scope when compared to the 2000 Community Exposure and Health Effects Assessment Program, will provide better information about airborne contaminants and human health over time. As well, identify how to reduce personal exposure factors from not only outdoor but indoor sources.

3.1 2005 Monitoring Year Sample

For the 2005 monitoring year, the sampling target was sixty (60) participants and this goal was meet despite a short fall of one participant from the Fort McMurray sample. As typical in these types of programs, a higher number of female participants were willing to participate, 69% (20/29) in the Fort McMurray sample and 63% (19/30) in Fort Chipewyan. Similarities included the marital status of the participants, where the majority of the participants were either in common-law or married relationships. Also, the majority of participants have resided in either community for less than five (5) years and spent the highest proportion of their day indoors at home.

Differences in the two samples were seen in the distribution of education levels and income levels. A higher proportion of participants from Fort McMurray (96.5%) indicated being involved in advanced education or developing trade skills than participants from Fort Chipewyan (73.3%). In addition, the Fort McMurray sample had a higher level of household income compared to those from Fort Chipewyan.

The number of participants who were active smokers in 2005 sample was also different in the two communities. At the time of this report, 26.7% of the Fort Chipewyan sample was current smokers versus 10.3% in the Fort McMurray sample. Exposure to second hand smoke however was similar for both samples, where approximately one-fifth of each sample allowed smoking in their homes or vehicles.

3.2 Measures of Exposure

Due to the small sample sizes taken from each community, it is difficult to draw firm conclusions as to how personal exposure to the measured airborne contaminants is occurring. As HEMP progresses, it is expected that a clearer understanding of how and what influences personal exposure will become better defined for each community involved in the program.

Nitrogen Dioxide (NO_2)

For both communities monitored in 2005, exposure to nitrogen dioxide (NO_2) was lower compared to existing guidelines. In Fort McMurray the median concentrations were 29.1 µg/m^3 (personal), 14.3 µg/m^3 (indoor) and 29.8 µg/m^3 (outdoor). While the levels of nitrogen dioxide were higher in Fort McMurray compared to the 2000 Alberta Oil Sands Community Exposure and Health Assessments Program, these increases are likely a result of increased population, industry and vehicle emissions within the community which are increasing personal exposure.

In Fort Chipewyan, the median concentrations were 9.6 µg/m^3 (personal), 7.3 µg/m^3 (indoor) and 2.4 µg/m^3 (outdoor). In comparison to Fort McMurray these levels are significantly lower and future monitoring will provide indications as to what levels of personal exposure are occurring in this community. For this monitoring period, indoor sources appear to be the major influence to personal exposure.

Sulfur Dioxide (SO_2)

Levels of sulfur dioxide (SO_2) measured in both communities were very low compared to existing guidelines. In Fort McMurray the median concentrations were 0.4 µg/m^3 (personal), 0.2 µg/m^3 (indoor) and 2.6 µg/m^3 (outdoor). The level of personal exposure to sulfur dioxide in the 2005 Fort McMurray participants is lower, although outdoor levels had increased compared to the 2000 AOSCEHEAP. Again, this increased sulfur dioxide level is likely a reflection of an increased population and industrial activities.

In Fort Chipewyan, the median concentrations were 0.4 µg/m^3 (personal), 0.2 µg/m^3 (indoor) and 1.0 µg/m^3 (outdoor). Of note, personal exposure levels to sulfur dioxide were the same as the Fort McMurray participants even though outdoor concentrations were lower. The reason for this same personal exposure may be determined over time with ongoing monitoring in this community.

Ozone (O_3)

Personal and indoor levels of exposure to ozone were very low with indoor and outdoor exposure levels lower than existing guidelines or reference values. In Fort McMurray, the median concentrations were 1.2 µg/m^3 (personal), 0.5 µg/m^3 (indoor) and 42.7 µg/m^3 (outdoor). From the 2005 Fort McMurray participants, the level of personal and indoor exposure to ozone had decreased, with a slight increase in outdoor concentrations compared to 2000 results.

In Fort Chipewyan, the median concentrations were 4.2 µg/m^3 (personal), 1.0 µg/m^3 (indoor) and 82.1 µg/m^3 (outdoor). The levels of ozone concentrations were higher in Fort Chipewyan when compared to the Fort McMurray sample. The large discrepancy in concentrations between personal, indoor and outdoor supports the inherent inaccuracy of using outdoor concentrations as a reflection of personal exposure. Especially in the light of the fact that ozone is destroyed as it chemically reacts with other components in the air.

Volatile Organic Compounds

Indoor concentrations were the predominant factor affecting personal exposure to volatile organic compounds (VOCs). Due to the low detection level of the majority of the outdoor monitors, outdoor sources of VOCs appear to be of minor importance. The exception to this statement is benzene which was detected by 98% of the outdoor monitors however outdoor sources do not appear to be contributing to personal exposure.

Three of the VOCs examined currently have ambient air quality objectives as determined by Alberta Environment. These three VOCs are benzene, ethylbenzene and toluene. It should be noted that all outdoor monitors were below their respective objectives.

Particulate Matter 2.5 ($PM_{2.5}$)

Outdoor $PM_{2.5}$ concentrations for both monitored communities were lower than current guidelines as well as the 2010 proposed Canadian wide standard. In Fort McMurray, the median concentrations were 14.9 µg/m^3 (personal), 7.3 µg/m^3 (indoor) and 6.9 µg/m^3 (outdoor). Levels for the three sampler locations in Fort McMurray had decreased in comparison to the 2000 community health assessment and exposure program. As the personal and indoor medians are not closely related, personal exposure could be influenced by other factors such as lifestyle choices (i.e. smoking) or occupation.

In Fort Chipewyan, the median concentrations were 26.1 µg/m^3 (personal), 20.3 µg/m^3 (indoor) and 3.3 µg/m^3 (outdoor). Although the personal median concentration is higher then the Fort McMurray sample, this exposure appears to be strongly linked to indoor source or lifestyle activities (such as smoking). The Fort

Chipewyan sample did have a slightly higher proportion of smokers which may have influenced this measurement. As the outdoor median concentration is low, outdoor source(s) do not appear to be attributing to personal exposure in this sample population.

3.3 Recommendations

1. Continued implementation of the Human Exposure Monitoring Program

A primary purpose of the program is to attempt to determine the effects of exposure of airborne contaminants particularly the effect of outdoor or ambient levels on human health. As it is known that these exposures are low, determination of these effects will have to be measured over the long term. In order to achieve this goal, HEMP must be continually deployed as per its prescribed schedule.

2. Amalgamation of participant data as HEMP progresses.

To determine long term health effects, methods must be devised to amalgamate each community's data to determine trending and measure potential health effects. Achievement of this goal may be partly accomplished by continuing to contact and enrol participants from previous years to determine how their personal exposure levels are changing over time.

3. Education of the general public about airborne contaminants and how to manage or reduce their exposure.

As in the 2000 Alberta Oil Sands Community Exposure and Assessment Program, the highest exposure to the measured contaminants appears to be related to indoor sources (e.g. tobacco smoke, off gassing from consumer products or combustion sources). While all the measured levels were low, improving the public's knowledge and understanding about how and where airborne contaminants may be found or created could reduce exposure regardless of source (indoor or outdoor). In addition, reducing indoor or other related sources may allow for a better measure of impact from outdoor sources.

4.0 Glossary

Absorption

- Process of absorbing or the condition of being absorbed

Benzene[36]

- A water-soluble volatile organic compound (VOC) which at normal temperatures is a liquid, but readily evaporates and small amounts are detectable in the atmosphere.
- Important sources are the combustion of petroleum fuels by motor vehicle engines and emissions associated with many industrial activities such as ore mining, wood processing, coal mining, textile manufacture, and processes used in the oil and gas industry.
- Other sources, of which cigarette smoking is a major one, make important contributions to the exposure of individuals.
- Benzene is a known carcinogen and appears on Health Canada's First Priority Substances List.

Chain of Custody

- Documentation of movement and location of a sample from the time it is collected to the time it is analyzed at a laboratory

Convenience Sampling

- Selecting individuals that are easiest to reach for a study

Decane[37]

- Colourless liquid with a gasoline like odour. Its vapour is heavier than air and may spread long distances and accumulate in low-lying areas. In its liquid form it can float on water and may travel long distances and or spread fire.
- Component of gasoline, jet fuel, kerosene and petroleum solvents such as white spirit; solvent; rubber industry; paper industry and a constituent of polyolefin manufacturing wastes**.**

Ethylbenzene

- A water-soluble volatile organic compound (VOC)
- Ethylbenzene is used primarily in the production of styrene; other uses include solvents in paints and varnishes, as products in synthetic rubber, household cleaning products, gasoline, pesticides, carpet glues, asphalt, and tobacco smoke.
- Ethylbenzene enters the atmosphere primarily from emissions and exhaust connected with its use in gasoline; more localized sources will be emissions, waste water, and spills from its production and industrial use.

Health Canada's First Priority List[38]

- The Canadian Environmental Protection Act (CEPA) authorizes the Minister of the Environment and of Health to investigate a wide variety of substances that may be present in the environment and cause adverse effects on the environment or on human health.
- This list includes 44 substances which are assessed to be "toxic or capable of becoming toxic". In this program, benzene, xylene and toluene were assessed and are on this priority list.

Heptane & Methylhexane[39]

- Methylhexane is an isomer of heptane as it has the same chemical formula as heptane but the atoms in the model are arranged differently.
- Both are a colourless liquid with a gasoline odour.
- Heptane is used as a solvent in glues, varnishes, cements and inks; used to extracting natural oils and fats; a major ingredient in gasoline and aviation fuel and in petroleum solvents such as petroleum naphtha and rubber solvent.
- Methylhexane is commonly found in paint and solvents.

Hexane[40]

- A volatile organic compound which colourless in its liquid state and has a mild, gasoline – like odour. It is both naturally and synthetically produced.
- Minor constituent of crude oil and natural gas, but also used in the extraction of vegetable oil from seeds such as safflower, cotton, soy bean and flax.
- Also used as a cleaning agent for textiles, furniture and leather industries.

Limonene[41]

- A type of volatile organic compound which is classified as a terpene. Terpenes are produced primarily by plants in the form of an essential oil.
- Colourless liquid at room temperature that takes its name from lemon, as it smells like this citrus fruit.
- Used in food manufacturing as flavouring and added to cleaning products such as hand cleaners and polishes to give a lemon-orange fragrance.
- Increasingly being used as an environmentally alternative to mineral oils as a solvent for cleaning purposes, such as the removal of oil from machine parts, being more easily biodegradable than mineral oils and produced from a renewable source.

Median

- The value halfway through an ordered data set, below and above which there lies an equal number of samples.

Method Detection Limit (MDL)

- The minimum concentration that can be measured and reported with confidence that the value is above zero -- that is, that the contaminant is actually present.
- In this program, three standard deviations above the mean method blank levels were used as the MDL.

***N*-propylbenzene**[42]

- A colourless volatile organic compound (VOC) with no detectable odour.
- Naturally found in petroleum and bituminous coal. It is released to the atmosphere in emissions from combustion sources such as incinerators, gasoline engines and diesel engines. Solvent evaporation, land filling leaching and general use of asphalt also releases it into the environment.
- Used in building and construction plastic form insulation, including pipe and block; other rubber floor and wall covering; scatter rugs and bathmats and sets; sheet vinyl flooring; wood office work surfaces (modular systems)**.**

Nitrogen Dioxide (NO_2)[43]

- For the purposes of air quality monitoring, oxides of nitrogen (NO_X) is considered to be the sum of nitric oxide and nitrogen dioxide; most oxides of nitrogen are emitted in the form of nitric oxide which will rapidly react with ozone in the atmosphere to form nitrogen dioxide.
- In Alberta, about 43% of oxides of nitrogen emissions are produced by transportation (primarily by vehicles), while 37% are due to industrial sources (oil and gas industries) and 18% as a result of power plants (based on 1990 emission estimates).
- Smaller sources of oxides of nitrogen include natural gas combustion, heating fuel combustion, and forest fires.

NHEXAS

- National Human Exposure Assessment Survey

Nonane[44]

- A volatile organic compound (VOC) which is colourless liquid with a gasoline like odour.
- Used as a solvent; important component of gasoline and petroleum solvents; manufacture of paraffin products; paper processing and rubber industry; synthesis of biodegradable detergents; jet fuel research and distillation chaser.

Octane[45]

- A colourless volatile organic compound (VOC), normally found in a liquid state at normal temperatures.
- Used in aerosol paint concentrates, eye preparations (mascara, eye shadow, eye liners), furniture polish and cleaners; laundry starch preparations; lubricating oils; all types of paint and paint thinners; wood office furniture and work surfaces (modular systems)

Ozone (O_3)[46, 47]

- Ozone is both a naturally occurring gas, generated in the higher layers of the atmosphere and a major constituent of photochemical smog.
- Unlike other pollutants, ground-level ozone is not emitted directly by man's activities, but is generated by a photochemical reaction of oxides of nitrogen (NO_X) and volatile organic compounds (VOCs) in the presence of sunlight.
- In Alberta, ozone concentrations are generally lower at urban locations than at rural locations due to the destruction of ozone by nitric oxide which is emitted by vehicles.
- In Alberta, maximum ozone values are generally recorded during the spring and summer months.

Particulate Matter (PM)[48]

- Particulate matter consists of a mixture of particles of varying size and chemical composition.
- Most man-made particles are in the range of 1 to 10 microns in diameter; particles less than 10 micrometers in diameter (PM_{10}) are considered to be inhalable particulates and are suspended in the air for an indefinite period of time.
- PM_{10} sources, which can be inhaled into the nose and throat but do not normally penetrate into the lungs, include windblown soil, road dust, dust resulting from other activities (e.g. harvest), and industrial processes, generally created during burning processes, consisting of fly ash from power plants, carbon black from diesel and gasoline engines, and soot from wood-burning.
- This program quantified the finer particles ($PM_{2.5}$ and less), which can penetrate into the lungs (respirable particulates), are typically secondary aerosols that form when chemical reactions occur between sulfate (from power plants) or nitrate (from motor vehicles and industry such as oil and gas plants) and ammonia or from sources such as compressor stations, household heating appliances, and forest fires.

Sulfur Dioxide (SO_2)[49,50]

- A water-soluble irritant gas and a major pollutant in the atmosphere formed during the processing and combustion of fossil fuels containing sulfur, for example from gas plant flares, oil refineries, pulp and paper mills, fertilizer plants, coal-fired power plants, power generating stations, metal smelters, and heating boilers.
- Sulfur dioxide (along with NO_X) has a number of other environmental effects including lake acidification due to acid rain, and associated corrosion of stone and metalwork.
- Sulfur reacts in the atmosphere to form sulfuric acid and acidic aerosols which contribute to acid rain; combines with other gases to produce aerosols which may reduce visibility causing haze over large regions.
- In Alberta, it is estimated that 42% of sulfur dioxide emissions are emitted by natural gas processing plants while oil sands and power plants produce 26% and 18%, respectively, based on 1990 emission inventory.

TEAM - Total Exposure Assessment Methodology

- Method developed by the USEPA to determine exposures of the general population to certain pollutants.

Toluene

- A water-soluble volatile organic compound (VOC).
- The largest chemical use for toluene is in the production of benzene and urethane; also used as a solvent, gasoline additive, and in the manufacture of explosives, dyes, cements, spot removers, cosmetics, antifreezes, asphalt, and detergent.
- Toluene is released into the atmosphere principally from the volatilization of petroleum fuels and toluene-based solvents and thinners, and from motor vehicle exhaust.
- Toluene appears on Health Canada's First Priority Substances List.

Volatile Organic Compounds (VOCs)

- Several thousand chemicals both synthetic and natural which contain carbon and hydrogen. Over 900 have been identified in indoor air, with over 250 recorded at concentrations higher than 1 ppb.
- VOCs produce vapors readily; at room temperature and normal atmospheric pressure, vapors escape easily from volatile liquid chemicals.
- VOCs include gasoline, industrial chemicals such as benzene, solvents such as toluene and xylene, VOCs can be emitted naturally or as by-products of industrial processes.
- In this program, sampling was undertaken for 14 different VOCs.

Xylene (*m*-,*p*-Xylene & *o*-Xylene)[51]

- A water-soluble volatile organic compound (VOC)
- Major environmental releases of xylenes are due to emissions from petroleum refining, chemical plants, automobile exhaust and volatilization when used as a solvent.
- Used in a variety of consumer products including gasoline, paint, paint thinners and removers, varnish, shellac, rust preventatives and cigarette smoke.
- Xylene appears on Health Canada's First Priority Substances List.

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