Analysis of Spatial and Temporal Variation Among Terpenes Derived from Cannabis and Forest Environments

Sierra Brown

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Committee:
Christopher Simpson
Gregory Bratman

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Abstract

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Sierra Brown

Chair of the Supervisory Committee

Christopher Simpson

Department of Environmental and Occupational Health Sciences

Background: Terpenes are a broad class of volatile and semi volatile organic compounds with over 40,000 different known structures, that are emitted by a wide variety of flora. Terpene concentrations vary in different forest settings. This can be due to different combinations of many factors that can cause fluctuations and changes in terpene emissions including the specific plant species present, chemical reactivity, emission rates, as well as weather conditions such as wind speed, wind direction, temperature, relative humidity, pressure, and rainfall. In the current project spatial and temporal variability in terpene concentrations will be examined in forest, urban, and cannabis manufacturing facilities using novel thermal desorption tubes that have been designed specifically for analysis of terpenes.

Methods: This study was broken up into two phases. The first phase selected the parameters for terpene sampling by selecting the Carbotrap® glass T420 thermal desorption tubes specifically for sampling terpenes as well as the sample duration, flow rates and sample volume for each sample. The sample period was set to 120 minutes at a flow rate of 200mL/min was chosen to allow for a sample volume of around 24L. This was chosen for the outdoor forest and urban park samples.

During Phase two, samples were taken at three urban park/forest environments and outside of two indoor grown cannabis facilities. Samples were taken with the sample parameters from phase one and two sample periods were carried out at each location.

Results: Indoor cannabis terpene profiles were observed to be different than the outdoor samples: β-myrcene was the most abundant terpene in the indoor cannabis facility samples, and terpene concentrations inside the cannabis facility were very high compared to the concentrations found in the outdoor forest and park locations. α-Pinene was the dominant terpene in most of the outdoor samples. Some samples collected were below the limit of detection for α-Pinene, but mostly the tubes were able to detect the most abundant terpenes present. Overall, the terpene data exhibit substantial variability at each location, however with the small sample sizes for all the sample locations it is not possible to state definitively whether this variability is driven by specific environmental conditions.

Conclusions: The terpenes in highest abundance for outdoor forest environments were α-pinene, followed by β-pinene, d-limonene, borneol, 3-carene among others in lower concentrations. The terpenes that were most abundant inside cannabis facilities were β-myrcene followed by smaller concentrations of α-pinene, β-pinene, and limonene. From the results of this study in outdoor forest settings and urban parks, larger sample sizes should be implemented in future studies to account for the high variability of terpene composition and concentrations.

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Chapter One: Background and Significance

Introduction

Health benefits have been shown to be highly associated with exposure to nature and forests(J.-C. Kim et al. 2019; Cho et al. 2017; Tsunetsugu, Park, and Miyazaki 2010; Furuyashiki et al. 2019). Previous studies have evaluated forest bathing (Shinrin-Yoku) and the health benefits that have shown that there is a correlation between these health benefits and extended time in nature (Cho et al. 2017; Tsunetsugu, Park, and Miyazaki 2010; Furuyashiki et al. 2019). Terpenes are found in the forest air and individuals are exposed to these compounds through inhalation. Several studies have suggested that terpenes may be responsible for some of the health benefits of nature contact, however in other settings, exposure to high concentrations of terpenes has the potential for adverse health effects (Manesse et al. 2020; Doty 2012; Furuyashiki et al. 2019). This proposed study will evaluate the utility of a novel thermal desorption tube for sampling terpenes across a wide range of concentrations and will investigate the abundance and variability in terpene concentrations in different environments, including forest settings and cannabis facilities.

Terpenes

Trees and Forest Setting

Each of the senses plays an important role in the health benefits that exposure to a nature environment provides(Manesse et al. 2020). Different forest environments have different chemicals present in the air as well as differing trees and forest densities (Tsunetsugu, Park, and Miyazaki 2010). The concentrations of these different chemicals that are released into the air are dependent on factors such as the type of forest environment, climate, and the time of year or season (Tsunetsugu et al., 2010). Among the many chemicals that are present in forest settings,

biogenic volatile organic compounds (BVOCs) such as terpenes are mainly found in the air of these forest environments (T. Kim et al. 2020). With over 40,000 known structures, terpenes are a very broad class of organic compounds that are classified as mono-, sesqui-, di, and tri terpenes based on the number of isoprene units incorporated into the structure of each chemical (Cho et al. 2017). Terpenes that are commonly found in Northern Hemisphere forest environments are emitted by the plants that are present in these natural settings, and the more abundant terpenes are mainly from conifer trees. The majority of the terpenes that have been measured in ambient settings are commonly found in forested areas that are found in the temperate zone in the Northern hemisphere (T. Kim et al. 2020). Some of the specific terpenes are that are more abundant are α-pinene, β-pinene, d-limonene among many others (Tsunetsugu et al. 2010). These terpenes and others have been assessed in several studies as having therapeutic benefits, and the specific pathway of the olfactory sense has been studied in a laboratory setting to assess these benefits (Koyama and Heinbockel 2020).

Terpenes found in Forest Settings

Specific terpenes are identified and are present in the forest samples taken from the Pacific Northwest forest environment. The trees that are most prevalent in the pacific northwest region and more specifically in Washington state, include cedars, firs, and hemlock ("Tree Species – Washington Forest Protection Association" n.d.). Each specific species of tree can have slightly differing terpene and terpenoid concentrations and presences can vary (Kopaczyk, Warguła, and Jelonek 2020). Common terpenes that are found in tree species include α-pinene, β-pinene, camphene and limonene (Pokorska et al., 2012). Looking directly at Douglas firs, known by the scientific name *Pseudotsuga menziesii*, α-pinene and camphene were found in high concentrations while 3-carene, β-pinene, and limonene were found to be lower concentrations

(Huber et al. 2005). Terpenoids emitted in the highest concentrations by Western Hemlock (*Tsuga heterophylla*) are α-humulene, β-caryophyllene, isobornyl acetate, and α-pinene (Lagalante and Montgomery 2003). Other terpenoids found in Hemlock species also include germacrene D (Lagalante and Montgomery 2003).

The most abundant terpenes detected in Norway spruce needles included α-pinene, Camphene, Bornyl acetate, Limonene, Camphenilol, Borneol, β-pinene, 1,8-Cineole, Tricyclene, Myrcene, β-Caryophyllene, α-Humulene, α-Terpineol (Martin, Gershenzon, and Bohlmann 2003). Other terpenes were present in lower concentrations including Camphor, Terpinyl acetate, Piperitone, and Longifolene among others (Martin, Gershenzon, and Bohlmann 2003). A few of the diterpenes that were also found in high concentrations including Manool, Dehydroabietate, and Sandaracopimarate (Martin, Gershenzon, and Bohlmann 2003). These terpenes were measured directly in the needles of the spruce, not the surrounding air. The data can be used to show the terpenes that would be potentially emitted into the air from the specific species. Scotch pine (*Pinus sylvestrus*) has terpenes such as 3-carene, β-myrcene, sabinene, terpinene and others (Kopaczyk, Warguła, and Jelonek 2020).

Grasses have also been known to emit different terpenes, these include higher concentrations of myrcene and limonene, and smaller concentrations of both , α- and β-pinene (Fukui and Doskey 1996). The grasses looked at in this study include crown vetch (*Coronilla varia*) and bluegrass (*Poa spp.*) from a site in the Midwestern United States. Bluegrass is one of the main types of grass that is found in the northern United States ("4 Best Grass Types in Seattle" 2021; Palit, Gramig, and DeKeyser 2021).

Table 1a lists concentrations of terpenes that have been detected in forest air.

Table 1a. Terpene concentrations (ug/m^3) from locations around the world. Bdl=below detection limit, N.D.= not detected. Calculated using standard temperature and pressure. (adapted from J.-C. Kim et al. 2019; assuumed P=1atm and T= 25℃ to convert from parts-per-trillion to mg/m^3)

Site (μg/m^3)	α-Pinene	β-Pinene	d-Limonene	3-Carene	Myrcene	Camphene
Seonam temple forest, Korea	0.178	0.211	0.072	bdl	N.D.	0.039
Oshiba plareau, Japan	0.390	0.145	0.412	bdl	bdl	bdl
Juknokwon forest, Korea	0.429	0.574	0.412	bdl	N.D.	0.067
Castelporziano, Italy	0.541	0.201	0.902	bdl	bdl	bdl
Chiaotou, Taiwan	0.557	1.410	bdl	bdl	bdl	bdl
Ilomantsi, Finland	0.557	0.089	0.056	0.122	N.D.	0.011
Blodgett Forest, CA, USA	0.580	1.730	0.423	1.170	0.056	0.033
Mainz, Germany	0.651	0.546	0.412	0.273	0.134	bdl
Austin Cary Forest, Fl, USA	0.696	0.479	bdl	bdl	bdl	bdl
Odae Chananmu forest, Korea	0.741	0.306	0.339	bdl	bdl	0.245
Djougou, Benin	1.670	1.110	0.278	bdl	bdl	bdl
Balbina, Amazonia, Brazil	6.130	2.790	1.950	bdl	0.278	0.557
Jönköping, Sweden	54.210	1.780	7.240	39.010	1.170	3.900

Cannabis Terpenes

There are around 140 terpenoids that can be found in Cannabis (ElSohly 2007). For indoor grown Cannabis, the main components are made up of monoterpenes followed by sesquiterpenes. β-Myrcene and limonene were most abundant in the indoor grown Cannabis while β-myrcene, caryophyllene, α-pinene, and α-terpinolene were most abundant in outdoor grown Cannabis. Other terpenoids of note would include α-humulene, y-terpinolene, 1,8-cineole, sabinene, and bornyl acetate, which were present in smaller quantities (ElSohly 2007). Terpene concentrations and composition can vary depending on the strain of the Cannabis being grown. Different stages of the cannabis growing, drying, trimming, and manufacturing processes may also have different concentrations of terpenes present as well as different terpenes in abundance.

Olfaction

Terpenes are the primary constituents of plant-derived essential oils. The olfactory pathway is one of the main exposure routes for essential oils and these responses are found to be generated in the olfactory epithelium in the lateral/ventral areas for these terpenes found in essential oils (Koyama and Heinbockel 2020). These areas were found to respond to the essential oils and the sensory neurons get projected to this area of the olfactory bulb as well as in the dorsal region. Specific odors generated responses in different parts of the olfactory bulb and suggested that understanding the way that the odors are received and analysis of the different regions of the olfactory bulb is needed to help understand the function of different compounds in essential oils. Factors that need to be considered when looking at the role of olfaction and how it is affected by specific essential oils and aromatic chemicals include the concentration, sensitivity, environment, specific features of the olfactory system, as well as past experiences and potential aversions to odors. Terpenes that are present in the essential oils may have other impacts that are not directly expressed in the olfactory system. It is noted that these olfactory receptors are involved in chemical reaction processes and are associated with changes of blood pressure as well as other physiological effects. Many studies were outlined that explained the different effects that specific essential oils have on the body and olfactory system (Koyama and Heinbockel 2020).

The terpene α-pinene, which is a component of a wood scent was evaluated for how it affects human physiological responses in a laboratory setting (Tsunetsugu, Park, and Miyazaki 2010). Different dilutions of this scent were used, and it was found that the lower concentrations of the α-pinene caused a decrease in the systolic blood pressure, based on the subjective comfortability self-evaluations of the scent and odor. For the highest concentration, there was not a decrease in the systolic blood pressure but in fact an increase in the pulse rate which was caused by the

"slightly uncomfortable" experience which was from the highest odor and concentration of the α-pinene. The lower concentrations of the α-pinene were shown to have a beneficial effect on the physiological state while the highest concentration and odor of the α-pinene were shown to not be beneficial and cause more of a stress response to breathing in the scent (Tsunetsugu, Park, and Miyazaki 2010). This stress response was potentially explained because there isn't an outdoor forest environment exposure that would be that high of a concentration and thus the body was not conditioned to be aware of this high of a concentration of the scent (Tsunetsugu, Park, and Miyazaki 2010). This preliminary study of the different responses to varying concentrations of a terpene present in the forest environment demonstrates that the olfactory sense does have a role in the overall physiological responses of the body. In addition, the potential soothing effects of the terpene limonene was assessed, and the researchers concluded that there was a decrease in blood pressure almost immediately as well (Tsunetsugu, Park, and Miyazaki 2010). This study only looked at the immediate effects of these two specified terpenes and not the potential long-term effects of continued exposure.

Cedrol, another terpene, can be extracted and isolated from cedar wood oil and has potential sedative effects and can cause changes in the parasympathetic and sympathetic nervous system activity (Dayawansa et al. 2003). Heart rate, systolic blood pressure, diastolic blood pressure, and respiratory rates of the subjects who were inhaling the concentrated samples of cedrol were observed. An increase in parasympathetic activity was observed while there was a reduction in sympathetic activity because of the decrease in the heart rate, systolic blood pressure and diastolic blood pressure after the exposure to the cedrol (Dayawansa et al. 2003). A reduction in the respiratory rate during the exposure was observed which concluded that there is a relaxant effect of the pure compound Cedrol (Dayawansa et al. 2003). Together, these studies

demonstrate that terpenes can have varying effects on different systems of the body and impact the body in different ways.

Exposure Limits for terpenes

Turpentine is mainly made up of terpenes- primarily α-pinene, with smaller amounts of β-pinene, d-limonene, camphene, 3-Carene, and Terpinolene (Masten, Haneke, and Box, n.d.). Turpentine is regulated and has a recommended exposure limit from NIOSH of 100 ppm (8-hr TWA), an IDLH of 800 ppm, and an OSHA PEL of 100 ppm (560mg/m^3) as an 8-hr TWA ("CDC - NIOSH Pocket Guide to Chemical Hazards - Turpentine" n.d.). This regulation on terpenes is the only occupational health exposure limit in the United States.

The ACGIH has a threshold limit value (TLV) of 20 ppm (112 mg/ m^3) for Turpentine and selected monoterpenes ("TURPENTINE AND SELECTED MONOTERPENES" 2021). The three monoterpenes listed include α-pinene, β-pinene, and 3-carene. Washington state has a permissible exposure limit (PEL) for airborne contaminants of 100 ppm (8hr TWA) and a short-term exposure limit (STEL) of 150 ppm for turpentine ("WAC 296-841-20025:" n.d.). Other countries have workplace exposure limit regulations such as the United Kingdom, with a 8hr TWA of 100 ppm, and a STEL of 150 ppm(Great Britain and Health and Safety Executive 2018) and Germany has the most conservative limit of 5 ppm 8hr TWA ("List of MAK and BAT Values 2017" 2017).

Weather and Terpenes

Weather has been shown to have an impact on the concentrations of terpenes that are emitted. This includes but is not limited to changes in humidity, pressure, temperature, rainfall, and sun

exposure (Vallat, Gu, and Dorn 2005). Rainfall has been seen to increase emission of terpenoids in fruit trees as well as increase emission during higher temperatures. The interaction of temperature and relative humidity play a factor in the emission rate of terpenes from trees. Each difference in weather component, reactivity and emission rate all play a part in the air concentrations of terpenes from different flora (J.-C. Kim et al. 2019; Vallat, Gu, and Dorn 2005).

Sampling and Analysis for terpenes in air

There are multiple ways in which air sampling for terpenes and VOC's can be conducted. The main analytical methods include Summa canisters, Tedlar® bag samples, sorbent tubes followed by solvent desorption, and sorbent tubes followed by thermal desorption. Each of these methods are followed with Gas Chromatography Mass Spectrometry (GC/MS) for analysis (Woolfenden 2010a; Eurofins 2014).

Summa Canisters are stainless steel spherical canisters that range from 1-6L in size. The canisters create a vacuum of pressure to pull air samples into the stainless steel enclosure to collect samples (Eurofins 2014). Summa canisters are passive samplers with no need for a sampling pump, have a chemically inert surface and a hold time for analysis up to 30 days. However, using canisters limits how many samples can be taken, is restricted by the size and availability of canisters, shipping and purchasing cost. The restriction on the ability to sample in large quantity makes Summa canisters good for small sample sizes but not for large scale sampling. Tedlar® bags can also hold air in an enclosed container but need to use a sampling pump to help pull air into the bag. They have a very short hold time of 3 days, are much less reliable because of issues with the bags and have a higher potential for leakage. They have the

advantage of being convenient, more readily available and more cost effective (in comparison to Summa canisters) (Eurofins 2014).

When using sorbent tubes there are two methods to extract terpenes and other organics: solvent extraction and thermal desorption. Solvent extraction uses a solvent and extracts terpenes from the sorbent tube which then can be injected into the GC/MS, this method of extraction reduces the sensitivity because only a small fraction of the total extract (typically 0.1%) is analyzed (Woolfenden 2010a). Thermal desorption involves heating and cooling of the sorbent tubes and for the terpene concentrations to be extracted to be analyzed by the GC/MS; the final stage of thermal desorption includes an extremely fast heating of around 100°C/sec (Woolfenden 2010a). Extracts from sorbent tubes that are analyzed using solvent extraction can be repeatedly analyzed because of the small amount of extract that is analyzed. Newer technology allows for the possibility of repeated analysis from thermal desorption tubes also, (Woolfenden 2010b). Sorbent tubes utilize a sampling pump to actively collect samples and with the size of the sorbent tubes they are more portable and can be used at multiple locations or with a larger sample volume, compared to Summa canisters or Tedlar bags. Storage time for sorbent tubes is recommended to be no more than 30 days but 15 days is encouraged (Woolfenden 2010b). Novel thermal desorption sorbent tubes can be reconditioned and sent back for further testing once analysis from the initial sampling has been completed (Supelco 2022; Woolfenden 2010b).

Summary

Terpenes are found in abundance in many different forest settings and occupational environments. However, there are limited measurements of air concentrations of terpenes in urban environments, and even fewer reports of terpene concentrations in the vicinity of cannabis production facilities. The use of the novel thermal desorption tubes will allow for quantitative

data showing the concentrations of specific terpenes in different environments and circumstances. Terpenes have been shown to have different health effects depending on the concentration and duration of exposure. Essential oils contain terpenes and have been demonstrated to elicit effects on health and physiology through the olfactory pathway. Concentrations of terpenes in the environment can vary depending on weather, density of forests, climate, and seasons. Different stages of the cannabis manufacturing process can also have differing amounts of terpenes present.

Specific Aims

The primary objective of this study aims to gather preliminary data to make parameters to measure concentrations of terpenes in forest and urban park settings. The following specific aims will look closely at the terpene's profiles from forest, urban park, and indoor cannabis facility samples. This preliminary data will be used as reference when conducting future studies.

Aim 1: Evaluate variability in terpene concentrations in samples collected from forested environments, urban parks, and both inside and outside cannabis production facilities.

Aim 2: Compare terpene composition profiles in forest environments with terpene concentrations associated with cannabis production facilities.

Chapter 2: Methods

Study Location and Setting:

Locations were chosen based on the flora present in the area for the forested environment samples and included both urban forests and an urban park with open greenspace. Sampling at the cannabis growing and manufacturing locations were categorized as grow room, trim room, and outdoor samples. The outdoor sample locations were chosen by the strongest cannabis smell. At the first cannabis facility this occurred where the warehouse door was continually opened. A second cannabis growing location was chosen and at this facility sampling took place at the store front as well as behind the building where manufacturing takes place.

Field work:

Terpene sampling tubes and devices:

The tubes utilized for the sampling were a novel Carbotrap® T420 Thermal Desorption (TD) tube designed specifically for sampling and analysis of terpenes (Millipore sigma, St Louis, MO). Both glass and stainless-steel versions of this tube were evaluated. These tubes are packed with two different graphitized carbon absorbents that trap and retain terpenes for analysis. The sorbent is hydrophobic and can be used in humid atmospheres, which aids in expanding the different potential sample environments. Glass tubes packed with Tenax® adsorbent were also evaluated for comparison with the Carbotrap® T420 tubes.

Pumps and Calibration:

Gilian GilAir Plus sampling pumps (Sensidyne, LP, St Peterberg, FL) were used for all samples taken. Calibration of these pumps was conducted using the DryCal Defender 510 calibration device (Mesa Labs Inc, Lakewood, CO) and the pumps were calibrated before

and after each sampling period. To do this, the DryCal calibration device was attached to a calibration tube and then to the Gilian GilAir Plus sampling pump. The calibration tube was a glass CT T420 tube that was reused for each pump calibration. The DryCal was run to record measurements continuously and the sampling pump was set on calibration mode. If the DryCal was not reading the desired flow rate, the pump was manually adjusted until the desired low rate was reached and then the average of 10 continuous readings was recorded as the flow rate for the device. This was repeated for every pump that was used in the field. After the sampling was completed, the pump would be reattached to the DryCal and calibration tube set-up and the reading on the DryCal would be recorded to look at how far the flow rate of the pump drifted from the beginning to the end of sampling.

Phase 1:

Initial testing was conducted in December 2021 and January 2022 at the Hamlin Park location and the first Cannabis manufacturing location respectively. This testing aimed to evaluate performance of the different materials of the thermal desorption sampling tubes which included glass CT T420, stainless steel CT T420, and glass Tenax® . For each location weather was recorded, including temperature (°F), pressure (hPa) and relative humidity (%) at the beginning and end of the sampling period (Appendix II: *Table II-1, Table II-2*). For rainy day scenarios, an umbrella was put over the air sampling collection apparatus to act as a barrier if there was any rain during the sampling period. Field blanks were taken at each location for quality control and quality assurance.

Hamlin Park

A location was chosen in Hamlin Park off the main walkway near a heavily wooded area to the west of the baseball fields. Fog/mist was present in the morning and disappeared by noon (Appendix II-*Figure II-1*). The location for the air sampling was chosen near lower hanging foliage because of the potential for the terpenes to be emitted from the branches in closer proximity to the sampling apparatus (Appendix II: *Figure II-2, Figure II-3*).

For set up and execution, first the sampling pumps were calibrated using the DryCal calibration device and a calibration tube, then the TD tubes were connected to tubing and the sampling pumps and set up with the sampling boxes and hanging apparatus. Once set up, all the pumps were turned on and start time was recorded. Six samples were collected, one glass CT T420 tube (UW01) was set to collect a sample volume of 25L, while the other 5 were collecting a sample volume of 100L (UW02-UW06). The sample UW01 was collected using a flow rate of 100mL/min for approximately 250 minutes to get a sample volume of 25L, while the other samples were collected at a flow rate of 200mL/min for 500 minutes to give a sample volume of approximately 100L. Each of the different tube types was utilized for the 100L sample volume, one glass CT T420 (UW02), two ss CT T420 (UW03, UW04) and two glass Tenax® (UW05, UW06). Two glass CT T420 tubes were used for field blanks: the end caps were opened to allow for contact with the ambient air and then immediately closed. Once sampling was complete the tubes were labeled and wrapped in foil and put into an empty paint can container for storage, then shipped and analyzed at Millipore/Sigma.

Cannabis Facility #1

A tour was given at the beginning of the sampling visit to cannabis facility #1 and helped to decide the three locations that sampling would take place. These three locations include: a

grow room with maturing cannabis plants, a trim room, and an outdoor location directly outside the facility. For the first location, the grow room with the most mature plants in the facility was chosen. The sampling set up was conducted at the front of the grow room within 6 inches of the cannabis plants (Appendix II: *Figure II-5*) and a visual of the density of the plants in the room can be seen in the appendices (Appendix II: *Figure II-6*). The second location was the trim room where trimming, grinding, and packaging takes place. The samples were taken at table height approximately 3 ft off the ground (Appendix II: *Figure II-7)*. The final (outdoor) sampling location was outside of a warehouse door that was opened frequently. The outdoor sampling set up included umbrellas attached to the sampling station because of the rain that was present during the sampling period (Appendix II: *Figure II-8*). This final sampling was cut short because of time constraints.

The first sampling location was in the grow room where both glass CT T420 and glass Tenax® tubes were used; there were a total of 6 samples taken. When in the grow rooms precautions were taken to minimize bringing in any harmful bugs to the growing cannabis plants. These precautions include wearing lab coats, gloves and spraying ourselves down with ethanol-based spray sanitizer. The sample volumes taken for the samples were set at 5L and 10L. For the 5L samples the flow rate was set to 50mL/min for 100 minutes and for the 10L samples the flow rate was set to 100mL/min for 100 minutes. This allowed for many rounds of sampling to be completed during the workday. The lower sample volume used at the cannabis facility compared to the Hamlin Park samples was because of the higher concentrations of terpenes known to be in the air during the cannabis manufacturing process, as well as the ability to smell the cannabis while in the facility.

For the Trim room, the sampling set up was similar, two rounds of 100-minute testing were conducted. During the two sampling periods, glass CT T420, stainless steel CT T420 and glass Tenax® tubes were used. The sample volumes were the same for these sample periods as well, with a sample volume of 5L and 10L. In addition to the samples taken there was also two TD tubes connected in a series to test if there was any breakthrough of terpenes from the first to the second TD tubes as a precaution to ensure saturation of the TD tube was not occurring. For the final location, outside one of the warehouse doors, the same sampling parameters were in place (100-minute sample, 50 ml/min and 100 ml/min flow rates) but because of time constraints the samples had to be stopped after only 45 minutes.
After each sampling period was completed, samples were labeled, wrapped in foil, and placed in the paint can container for storage.

Phase 2:

Preliminary testing found that the maximum flow rate for the Gilian GilAir Plus sampling pumps in combination with the CT420 TD tubes was 200mL/min because the pumps would fault above that set flow rate. This aligns with the recommended flow rate from the TD sampling tubes between 0.02 and 0.250 L/min (Supelco 2022).

Locations

Three different greenspaces were chosen in the Seattle area for sampling. Maple Leaf Reservoir was chosen for a green space with minimal trees in the immediate vicinity (Appendix II-*Figure II-9, II-10, II-11*). Hamlin Park was chosen for low hanging trees and old growth (coniferous) trees (Appendix II-*Figure II-13*), and a location in the Arboretum was chosen for trees with no low hanging branches, and oak trees (Appendix II-*Figure II-*

12). Samples were collected outside of two cannabis facilities (cannabis facility #1, cannabis facility #2; specific business names redacted for privacy) (Appendix II-*Figure II-14, II-15, II-16, II-17*). Weather data for all locations can be found in Appendix II- *Table II-3*).

For each of the locations, the set up and execution of the experiment was the same. First each sampling pump was calibrated using the DryCal calibration device and a glass CT T420 calibration tube. Once the average flow rate was recorded, the glass CT T420 tubes were connected to tubing and the sampling pumps, and then set up in the sampling box and hanging apparatus. Once set up, all the pumps were turned on to run at a flow rate of 200mL/min for 120 minutes, at heights of 2-4 ft off the ground and start time was recorded. Based on the flow rate and the amount of time for sample collection, the sample volume collected for each of the sample was approximately 24L. Additional notes were taken for any abnormalities or changes in weather. Field blanks were taken approximately after every 10-15 samples.

For the samples taken outside of cannabis facility #1, a location outside of the warehouse door that was frequently opened was chosen, the door was opened at least 20 times during the 120-minute sampling period. For the cannabis facility #2 location, sampling was conducted with the sampler inlets hanging outside of a parked car because of the specific outdoor area that the samples were being taken. One set of samples was taken outside the back of the facility which is near an urban setting of homes with yards while another sampling day was taken outside the store front of cannabis facility #2. The front door of cannabis facility #2 was opened over 30 times during the 120-minute sampling period.

Terpene sample storage and analysis:

Before sample collection, the tubes were stored at room temperature. Each day, once the samples were collected and labeled (Appendix II-*Table II-4*), they were kept in a refrigerator at a stable temperature between 4-25°C until they were able to be shipped for analysis. To ensure a more stable temperature, the samples are shipped with ice packs to a commercial laboratory for analysis (Supelco 2022).

Data Analysis:

Analysis was carried out by the commercial laboratory following the EPA TO-17 reference method, and analyzed via Automated Thermal Desorption Gas Chromatography Mass Spectrometry (ATD-GC-MS). TD tubes were analyzed using a Perkin Elmer TurboMatrix 650 ATD, Clarus 680 GC, and Clarus SQ8T MS.

A sample is first dry purged at ambient conditions using high purity helium to remove excess air and moisture. The sample is then heated to thermally desorb analytes off the sorbent material (primary desorption). Analytes are then refocused onto a secondary focusing trap. This trap is cooled and then rapidly heated (secondary desorption). Sample splitting was utilized at the inlet and outlet of the focusing trap by controlling the flow of carrier gas, helium.

Analytes were injected from the trap to the GC column via a heated transfer line. A Restek Rsi-5Sil MS column was utilized for terpene analysis. Analyte mass-to-charge ratios (m/z) were acquired using electron ionization at a scan range of 40 to 265 atomic mass units.

Analytes present in each sample were quantified against calibration curves of instrument response vs. known analyte concentrations. A *m/z* unique to the mass spectrum of each target analyte was used as the instrument's response.

Statistical Analysis:

Summary statistics (mean, standard deviation) were calculated using Microsoft excel. Prior to calculating summary statistics, and values less that the laboratory reporting limit (expressed as $\mu g/m^3$ and assuming a nominal 24L sample) were substituted with the reporting limit divided by the square root of two. The students' t-test, implemented in Microsoft excel, was used to compare average terpene concentrations between locations.

Chapter 3: Results

Phase 1:

The preliminary study results found that when sampling outdoor forest environments 25L samples provided adequate limits of detection. In *Figure 1,* the terpene concentrations sampled from Hamlin Park in December show that the 25L sample had higher concentrations in relation to the 100L sample – though this difference could be due to spatial or temporal variations in ambient terpene concentrations between these two locations, or to non-linearity of the calibration curves used to quantify these samples. Both samples were taken using the Glass CT T420 tubes.

Figure III-1 in Appendix III shows the difference between glass CT T420 tubes and glass Tenax® for the same sample volume of 100L collected at the Hamlin Park location. The glass CT T420 tubes had a higher concentration of terpenes and thus was chosen for all subsequent samples in Phase 2.

Figure 2 compares the glass vs stainless steel CT420 tubes. While most compounds showed similar concentrations in both types of tube, both α- and β-pinene were lower in the stainless steel tubes vs the glass tubes. *Figure 3* also looks at the comparison of glass and stainless-steel CT T420 tubes, inside the trim room of Cannabis facility #1, the concentrations for all of the compounds were consistently higher for the glass tube vs the stainless steel CT T420 tubes. Consequently, glass CT420 TD tubes were chosen for phase 2 of the study.

Table III-1 in Appendix III outlines the results from all tube measurements with the 7 terpene compounds.

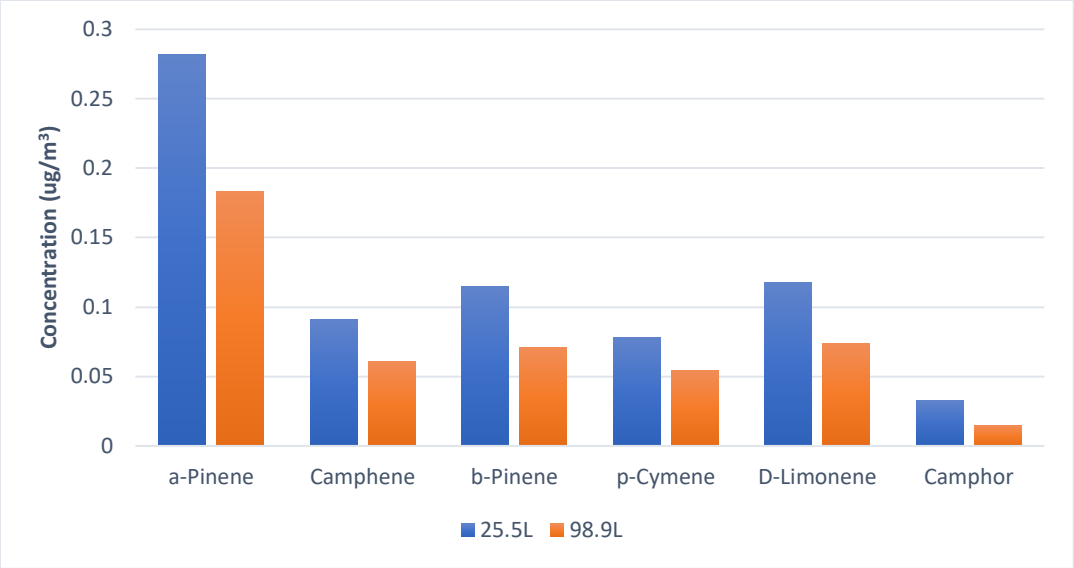

Figure 1. Hamlin Park 12/7/21 Glass CT T420 tube Terpene concentration($\mu g/m^3$) for different sample volumes (L)

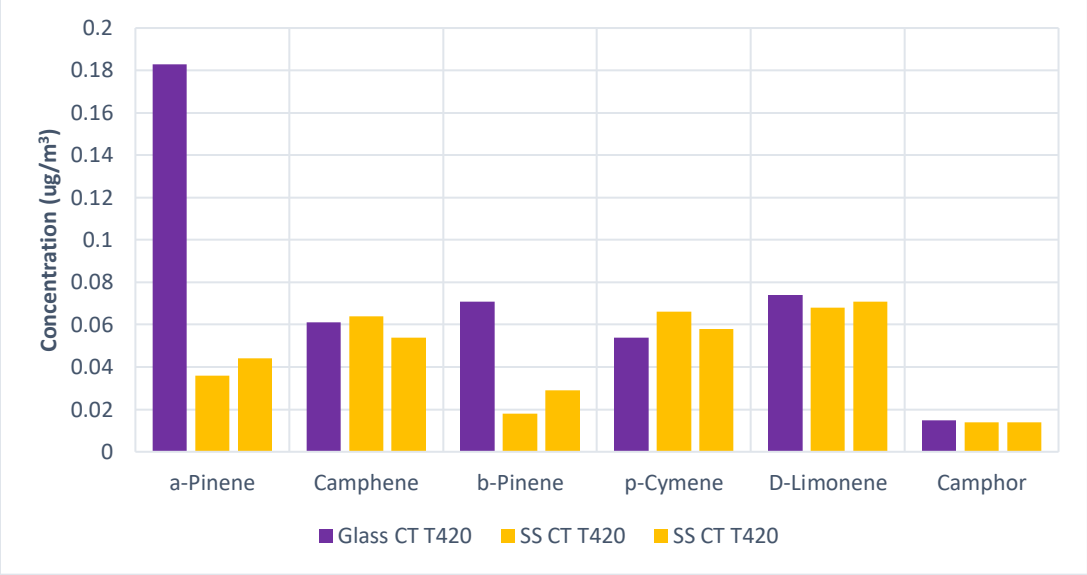

Figure 2. Hamlin Park 12/7/21 Sample Terpene concentrations($\mu g/m^3$) for Glass and Stainless steel CT T420 Tubes (all 100L samples)

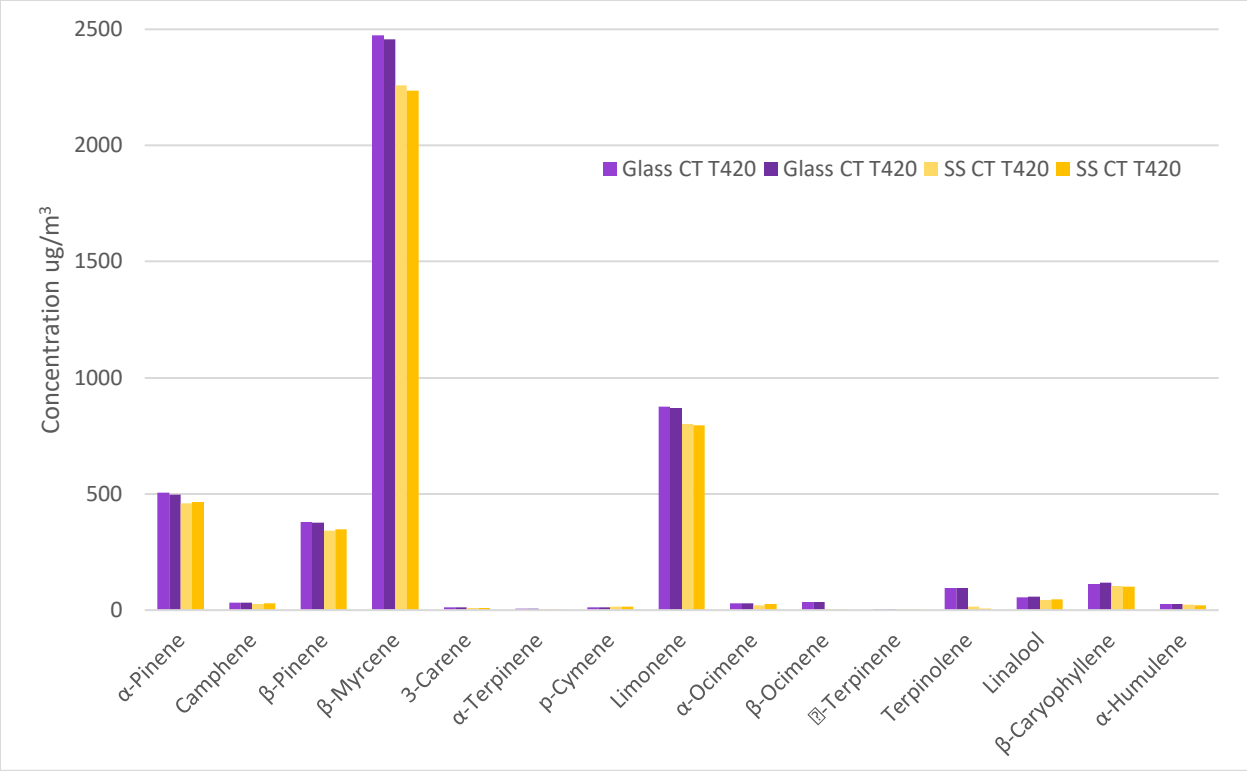

Figure 3. Indoor terpene concentrations(µg/m^3) from Trim room at Cannabis Facility #1. Glass and Stainless-Steel CT T420 tubes (all 5L samples) 1/11/22

The samples taken indoor at cannabis facility #1 had high concentrations for β-myrcene, limonene, and α-pinene in both the grow and trim room. β-Myrcene was higher on average in the grow room (2140 µg/m^3) than the trim room (2030 µg/m^3), but all the other terpene concentrations recovered were more abundant on average in the trim room than the grow room. These findings can be seen in *Figure 4* below as well as in *Table III-2* in the Appendices. *Figure III-2 and Figure III-3* in the Appendices show the terpene concentrations for each sample taken indoors on 1/11/22. The outdoor cannabis terpene samples were cut short due to time constraints and terpene concentrations were below the limit of detection for those samples. However, the analytical laboratory subsequently optimized their assay conditions to provide improved limits of detection for phase 2 of their study.

As mentioned in the methods section, in addition to the samples that were taken in the trim room, two different samples had two TD tubes connected back-to-back to test for potential breakthrough and saturation of the sampling tube terpene concentrations were expected to be highest in the trim room. This was used as a precaution to check quality control and quality assurance, and the analysis concluded that the secondary tubes had no contamination, so the tubes were not being saturated and there was no breakthrough of terpene concentrations with the single tube sampling method.

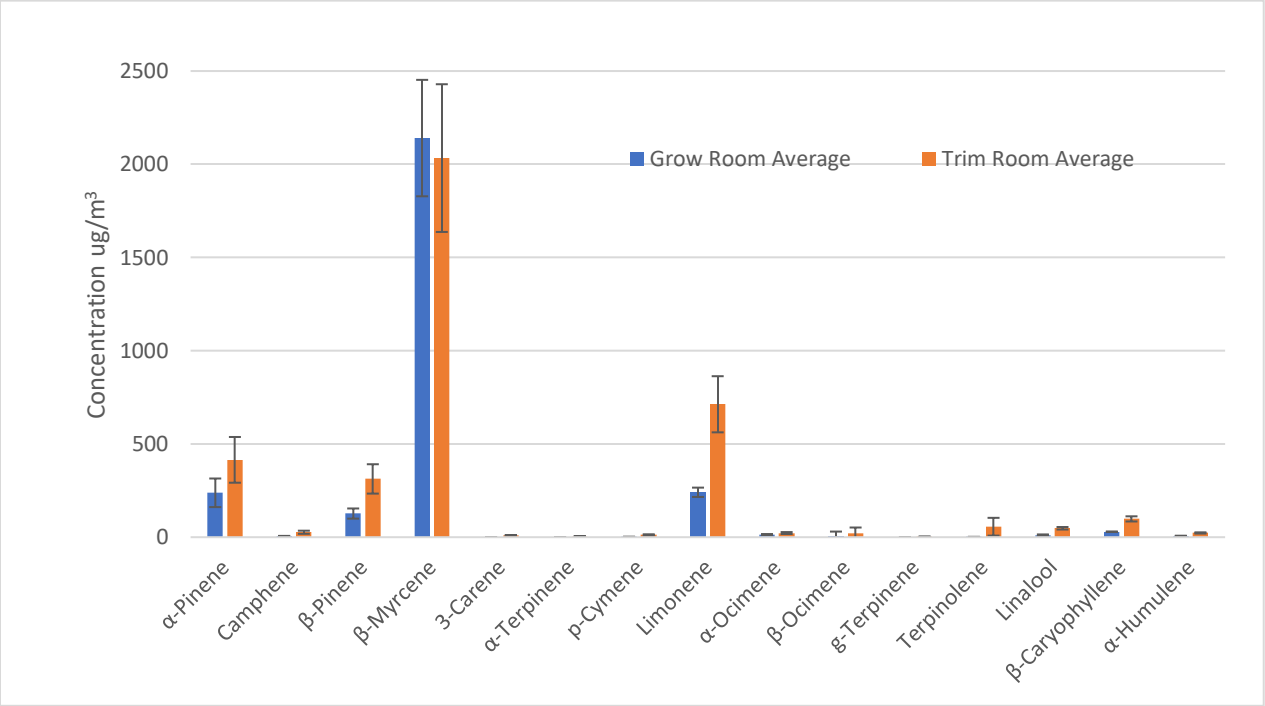

Figure 4. Average Terpene Concentrations in Grow and Trim Room at Cannabis facility#1 1/11/22

Phase 2:

Contamination of field blanks was detected for several terpenes on only one out of the three field blanks, in the range 0.045-0.378 μg/m^3. The field blank data is summarized in the appendix in *Table III-3,4.* Data was also provided for on laboratory blank. The only

contamination detected in the laboratory blank was β-carophyllene (0.015 μg/m^3), α-humulene (0.043 μg/m^3), β-myrcene (<0.001 μg/m^3) and α-terpineol (0.003 μg/m^3). Accuracy for the phase 2 samples, based on analysis of a spiked TD tube, ranged between 96-128%.

The laboratory altered their sample analysis parameters partway through analysis to provide greater sensitivity after the analysis of 3 samples (UW100-102) which resulted in two sets of reporting limits.

One field blank (UW100) was analyzed with the first set of analytical methods which had a reporting limit range of 0.042-0.417 μg/m^3 (outlier of 8.792 μg/m^3 linalool). Nine terpenes in that blank (UW100) were above the reporting limits, ranging from 0.047-0.378 μg/m^3.

The field blanks analyzed with the more conservative reporting limit had a reporting limit ranging from 0.01-0.04 μg/m^3. The two field blanks (UW116, UW125) analyzed with these limits did not have any concentrations above the reporting limit.

The outdoor forest environment samples show that there were many overlapping similarities in the terpenes found in all the greenspaces. The four highest concentrations were α-pinene, β-pinene, d-limonene, and borneol which can be seen in *Figure 5* below. All the average concentrations listed in *Figure 5* show that Hamlin Park had on average a higher concentration of terpenes compared to both Maple Leaf Reservoir Park and the Arboretum. Maple Leaf had a higher concentration of α-pinene, β-pinene, and camphene than the Arboretum where the trees were closer in proximity to the sampling equipment set-up than at Maple Leaf Reservoir Park.

Maple Leaf Reservoir Park had extremely low concentrations of d-limonene with respect to the two other forest environments listed.

This figure looks at the average terpene concentration found in the three forest environments Hamlin Park dominated for all the terpene concentrations, but there was a high degree of variability. Many of the samples had different terpenes that fell below the reporting limit (see Appendix 3, *Table III-5*). Concentrations were similar at the other two locations and were highly variable as well.

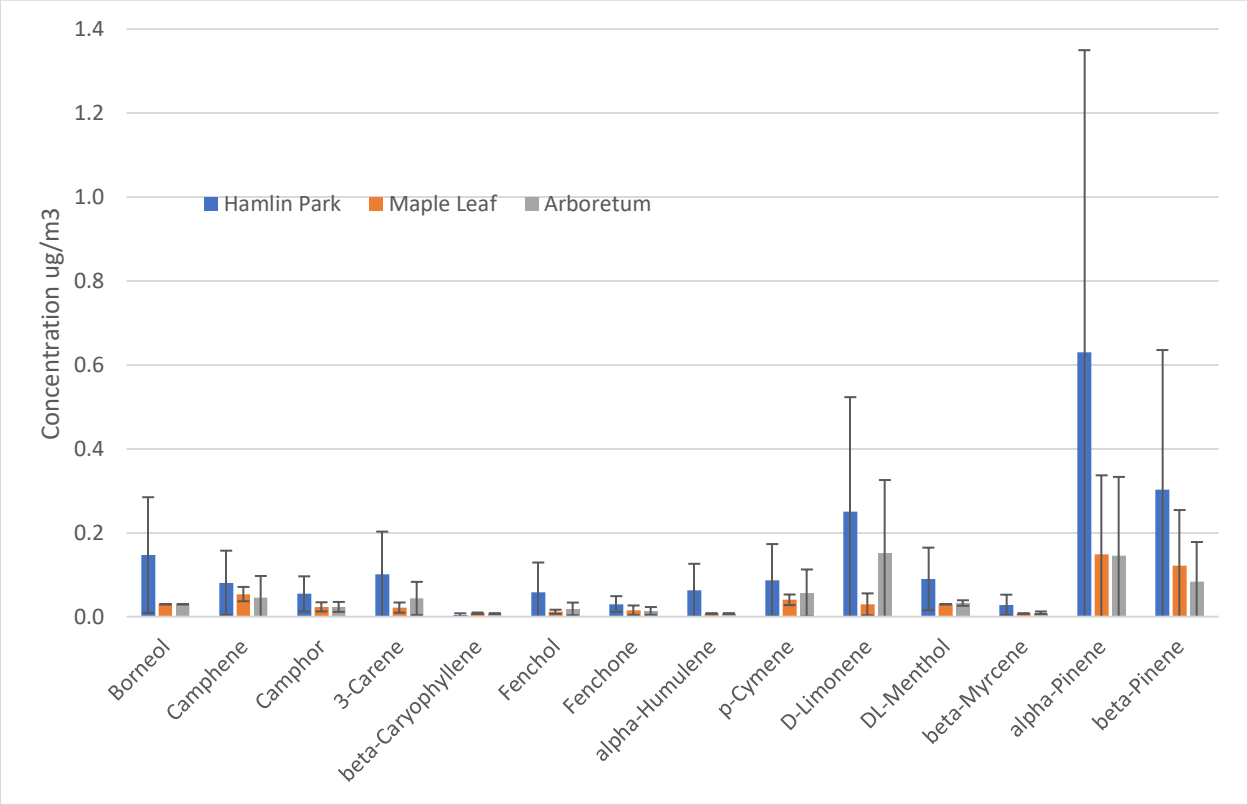

Figure 5. Hamlin Park, Maple Leaf Park, and Arboretum average terpene concentration samples from 5/12/22-5/17/22

Figure 6 looks specifically at the two sampling periods at Maple Leaf Reservoir Park. These two sample periods were collected 1 day apart, and many differences can be seen in the average terpene concentrations. The samples collected on 5/13/22 had lower concentrations of both α-pinene (0.007 μg/m^3) and β-pinene (0.015 μg/m^3), compared to the samples collected on 5/14/22 that had drastically higher terpene concentrations of both α-pinene (0.288 μg/m^3) and β-pinene (0.227 μg/m^3). The differences in these two collection periods were the weather, with 5/13/22 having mostly sunny weather with 9mph winds and 5/14/22 used an umbrella during sample collection because it was raining and there was no wind present during sample collection. The samples collected during the sunny day (5/13/22) had the highest concentrations of the terpenes camphene, camphor, p-cymene, and fenchone, while the rainy-day sampling (5/14/22) had the highest concentrations of α-pinene, β-pinene, and camphene.

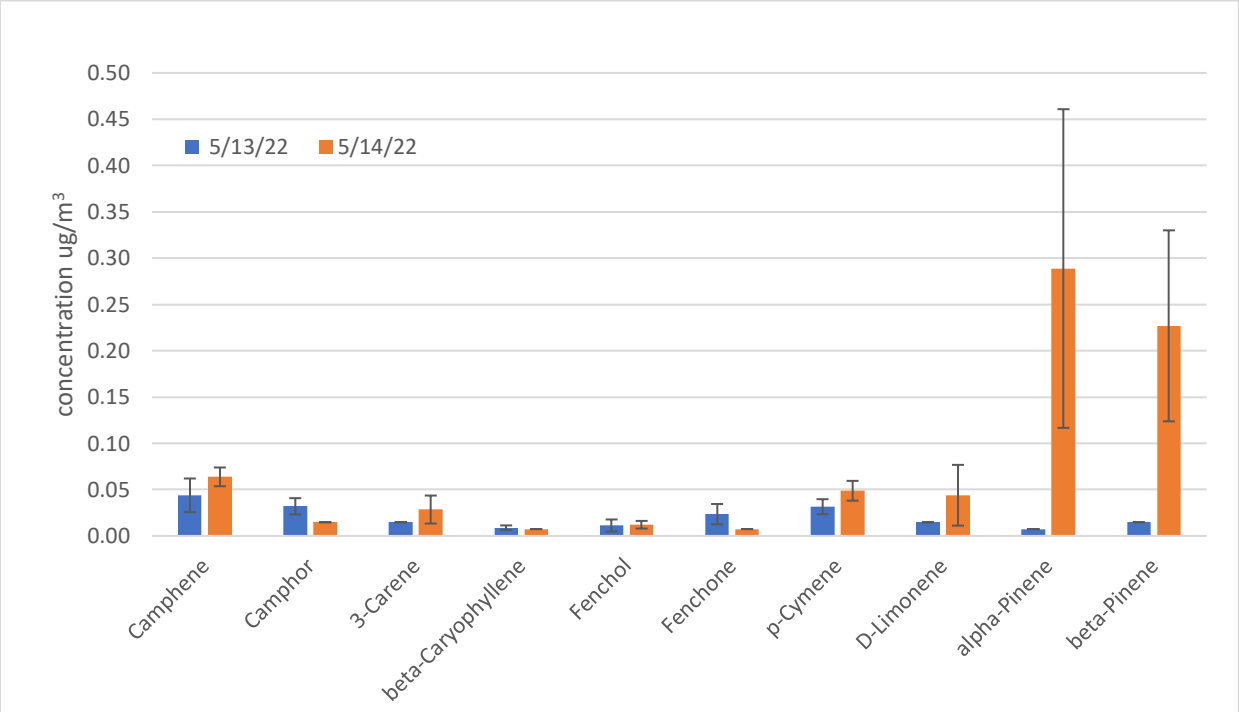

Figure 6. Outdoor sample mean for each sampling period at Maple Leaf Reservoir Park

Figure 7 summarized the outdoor air terpene concentrations from the cannabis growing facilities. The graph separates the two cannabis facilities as well as a separation of facility #2 has a denotation for outside the back as well as the front of the facility where two sample periods were collected. Cannabis facility #2 front sampling location was dominated by d-limonene (2.404 μg/m^3) while cannabis facility #1 and the back sampling location of cannabis facility #2 have similar terpene profiles to the outdoor samples and is dominated by α-pinene (0.306 μg/m^3, 0.428 μg/m^3 respectively).

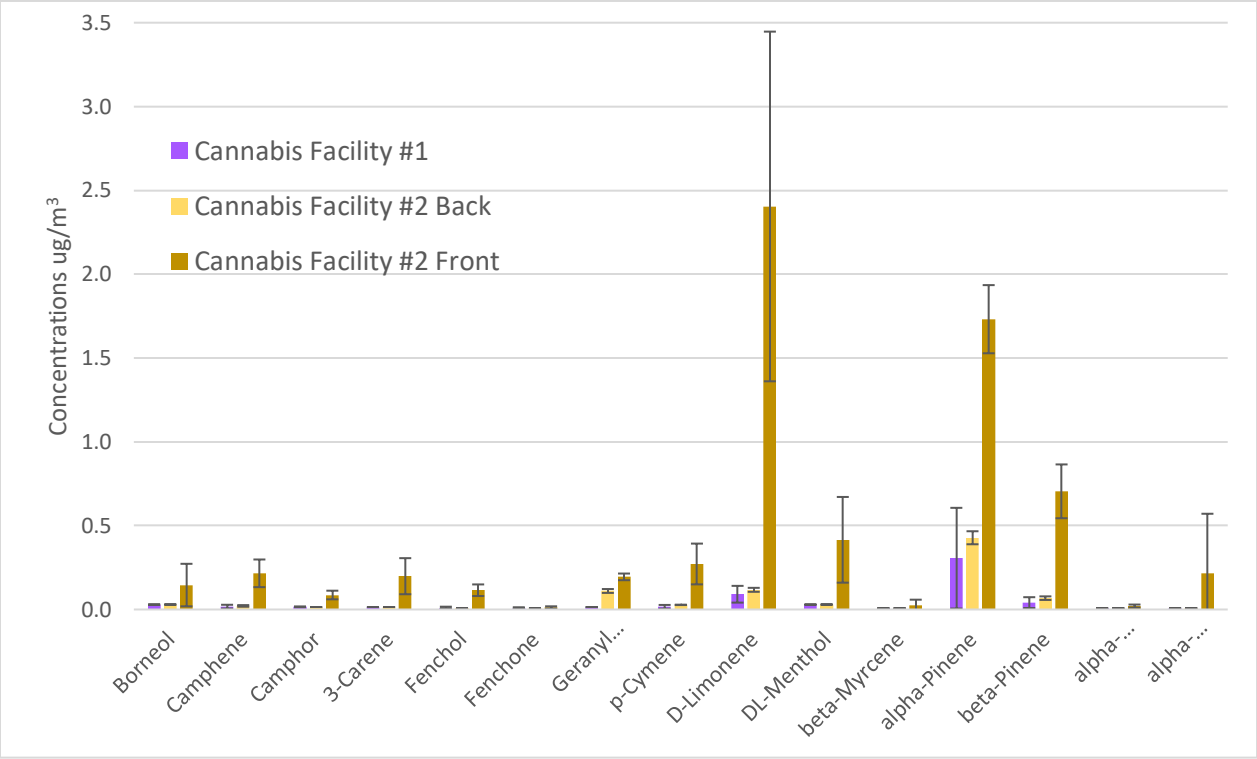

Figure 7. Outdoor mean terpene concentrations(ug/m^3) at the Cannabis Facilities

Discussion

Phase 1

Initial challenges for Phase 1 at Hamlin Park happened at the beginning of the day with a few of the sampling pumps. These issues were found to be caused by low battery readings or incorrect program settings that were only able to be corrected once back in the lab. Even with these minor setbacks, proposed sample volumes were nearly met with the continued observation of the pumps to ensure that they were continuing to work correctly. If one of the sampling pumps stopped working correctly, the pump was changed out for another pump to continue the sample with proper air flow through the sampling tube.

The results of phase 1 samples showed that there was adequate sensitivity in the 25-liter samples and that the Carbotrap® CT T420 glass tubes were the tubes best suited for terpene sample collection with the higher concentrations measured from the glass tubes in relation to the stainless-steel tubes used – particularly for α-pinene and β-pinene. The outdoor forest environment samples established a baseline terpene profile as well as potential concentration trends for Hamlin Park.

Indoor cannabis terpene profiles were observed to be different than the outdoor samples: β-myrcene was the most abundant terpene in the indoor cannabis facility samples, and terpene concentrations inside the cannabis facility were very high compared to the concentrations found in the outdoor forest and park locations. The indoor trim room also showed differing concentrations for the first sampling period versus the second. The first sampling period was when there was more work being conducted during the 100-minute time frame while the second time frame starting at 14:30 had lower concentrations but the same terpene profile. This can be

seen in *Figure 7*, where there is a lower concentration found for all the terpenes in both sampling periods.

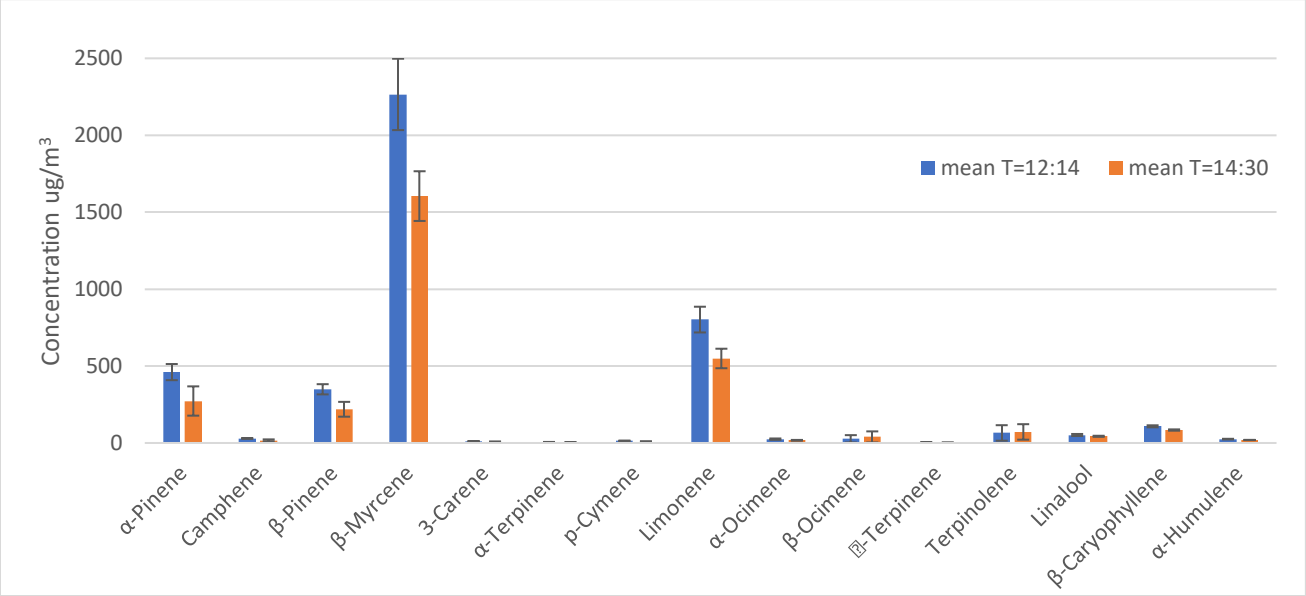

Figure 7. Indoor Cannabis Facility #1 Trim room mean terpene concentrations µg/m³ for sample periods starting at 12:14 and 14:30 (24hr time).

Phase 2

Field Blanks:

Two of the three field blanks that were taken over the course of the week-long sampling period of 5/12/22-5/19/22 had no detected terpene concentrations above the most conservative detection limits. One field blank did exhibit terpene contamination. It is tempting to say that there was a mislabeling of that specific sample but because of many of the samples also had primarily non detects we can't with confidence conclude that mislabeling of that field blank occurred. Overall, the field blanks suggest that there was little to no contamination of the tubes in the field.

Outdoor samples

The samples that were taken helped to establish a set of sampling conditions to accurately measure ambient terpene concentrations in outdoor samples; these parameters also worked inside of cannabis farms and facilities, although the instrumental analysis conditions had to be adjusted to balance providing adequate sensitivity for ambient samples, without overloading the GC system with the samples from inside the cannabis facility. The sampling conditions chosen also provided adequate sensitivity for most but not all terpenes collected in ambient samples. T-tests were performed to compare the means between different forest locations. These tests show that there is no statistically significant difference in the mean concentrations between the outdoor locations (Appendix III-*Table III-8*). A few of the samples collected were below the limit of detection for α-pinene which is the dominant terpene in most of the outdoor samples, but for the most part the tubes were able to detect the most abundant terpenes in Hamlin Park. *Figure 8* shows the different terpene concentrations found at Hamlin Park during each sampling period, they are 24-25L samples. The highest concentrations for each sampling period were α-pinene, β-pinene, and d-limonene, among others listed from the more sensitive analysis that was conducted with the samples collected in May 2022.

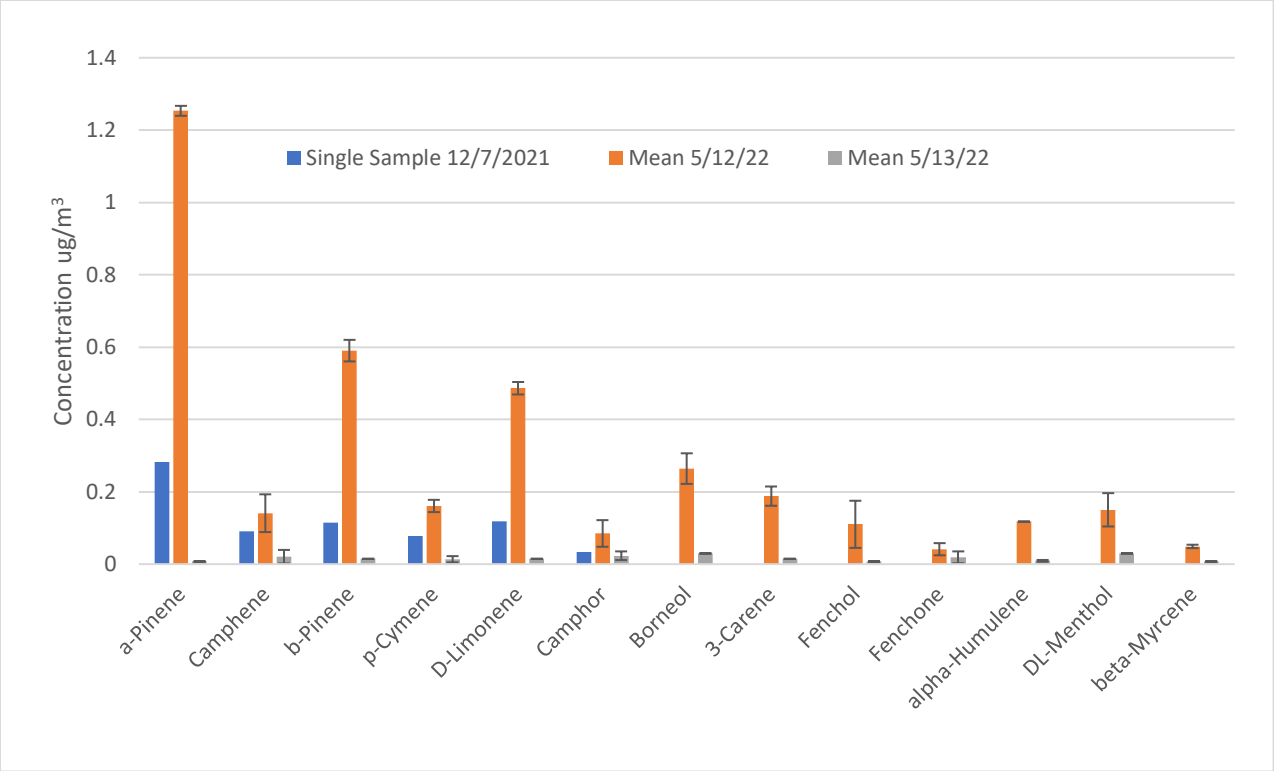

Figure 8. Terpene concentrations found at Hamlin Park during three different sampling periods. The single sample only had detection for the first 6 terpenes listed.

Table 1. Hamlin Park weather data for all sampling periods

Date	Location	Time (24 hr)	Temp (°F)	Relative humidity (%)	Pressure (hPa)	Wind (mph)	Wind Direction	Conditions
12/7/21	Hamlin Park	8:35	44	100	1014	5	SE	Fog, overcast, light rain
5/12/22	Hamlin Park	13:29	48	81	1015	10	SSE	heavy Rain whole sample period
5/13/22	Hamlin Park	10:02	47	68	1024	8	SSW	Sun breaks, cloudy

Weather differences can also be seen in *Table 1*, the dates 12/7/21 and 5/12/22 had higher concentrations of terpenes and also had higher relative humidity and lower pressure as well as overcast with rain present during the sampling periods.

Similar associations between weather and terpene concentrations can be seen in the data collected from Maple Leaf Reservoir Park. *Table 2* shows that the higher concentrations of terpenes were collected during the sampling on 5/14/22 of sampling. The relative humidity was higher on 5/14, the pressure was lower and there was no wind with overcast and rain compared to the 5/13/22 sampling where the weather was sunny and windy (Appendix 2, *Table II-3*). Overall, the terpene data exhibit substantial variability at each location, however with the small sample sizes for all the sample locations it is not possible to state definitively whether this variability is driven by specific environmental conditions.

Table 2. Maple Leaf Reservoir Weather data

Date	Location	Time (24 hr)	Temp (°F)	Relative humidity (%)	Pressure (hPa)	Wind (mph)	Wind Direction	Conditions
5/13/22	Maple Leaf Reservoir	7:27	45	75	1024	9	SSW	Sunny with clouds
5/14/22	Maple Leaf Reservoir	8:30	48	83	1015	No Wind	N/A	Overcast with rain showers

Outdoor Sampling of Indoor Cannabis Facilities

The indoor sample concentrations from facility #1 show that β-myrcene dominated the samples, along with limonene. When looking at outdoor samples from the same facility, that

sample trend did not follow. There was barely any β-myrcene found in either of the outdoor cannabis facility samples. The only outdoor sample that had either of the two terpenes that were present at high levels in the indoor samples was from the front of Cannabis Facility #2, where d-limonene was present. The front of Cannabis facility #2 also had the strongest odor for the entirety of the sampling period. Cannabis Facility #1 had odor present to a lesser degree and only when the door to directly next to the sampling set up was opened and workers from inside the cannabis facility walked by.

For facility #2 samples, one sample day was conducted near the back of the facility, which was found to have a terpene profile similar to the outdoor urban and forest environment samples which was similar to facility #1, while the front of facility #2 where samples were collected from the front of the building found that the terpene concentrations of those samples were dominated by limonene and α-pinene which was a more similar terpene profile to the indoor cannabis facility terpene profile. The front of Cannabis Facility #2 had strong consistent odor while sampling, while the sampling period collected from the back of the cannabis facility #2 building had no odor at all.

Limitations

There were several limitations to this study; most were due to time constraints. Small sample size is one of the most prominent limitations of this study. This limitation was due to time constraints for collection of samples, limited budget for sample analysis, limited number fittings for the tubing, sample pump's battery life limiting the number of samples that could be collected in one day. The sample pumps were able to run for two 2-hour sampling periods

but after 4 hours of run time, the sampling pumps need to be charged. There are currently 6 fittings that connect the TD tubes to the tubing and pumps for sample collection so that was a limiting factor as well. Time constraints regarding collection, shipping, and analysis retrieval played a role as well.

The analytical methods and reporting limits were altered multiple times during the study. This made comparison a bit difficult because of the different parameters surrounding the reporting limits. By the end of the second phase of sampling, the lowest set of reporting limits were obtained which helped to analyze even the smallest concentrations of terpenes that were sampled. Because the first few samples were analyzed with higher reporting limits, it is possible that smaller concentrations of terpenes were potentially present in these samples but were below the detection limits.

During analysis, there is the potential for interference from different compounds that have similar retention time and mass-to-charge ratio. This occurred with linalool, which had interference from dodecane under the sampling and analysis conditions used, and because of this a reasonable reporting limit was not able to be found. This also brings up the interference of external factors present in the air. At all of the locations sampled there was a road nearby and car exhaust, as well as the possibility for recreational or medicinal cannabis use, wildfire smoke, or other compounds present in the air and could interfere with sampling and analysis of the terpenes.

Future Areas of Study

From the results of this study in outdoor forest settings and urban parks, moving forward larger sample sizes should be implemented. More samples should be obtained at each of the locations sampled, as well as including more locations of sample collection. Since the sample collection period was over a short period of time, different seasons and weather conditions with larger weather variations would be helpful in deciphering the effect of weather/environmental conditions on the ambient terpene concentrations. Together with larger sample numbers because of the very small sample size of 2-3 samples during each 2-hour sample period, more locations within the park location would give ample comparison to how varying the different areas of the urban park can be with the potential for different terpene profiles and concentrations.

With the preliminary work done outside of the indoor cannabis facilities, more sampling outside these establishments would give a better idea if there is a cannabis signature profile for outside these cannabis growing and retail facilities, or if the concentrations are varying based on the outdoor surroundings or indoor cannabis being grown and processed.

Future health studies related to terpene exposure in both cannabis facilities and outdoor forest settings and urban areas would be another step in learning more about the different effects that terpene exposure has on the body. Health data, such as heart rate, blood pressure and differences before and after exposure could be measured from cannabis workers in the facility as well as in forest bathing studies.

Conclusions

This preliminary study allowed for the establishment of a set of sampling conditions that can accurately measure ambient outdoor terpene concentrations. These sampling parameters were also able to be altered and used to sample inside of cannabis farms and facilities with higher concentrations of terpenes. Novel Carbotrap® thermal desorption tubes specifically for measuring terpene concentrations were used and after preliminary sampling, the glass CT T420 tubes were chosen in preference to the stainless-steel CT T420 tubes because of the higher yield of both α-pinene and β-pinene. Sample volume was chosen to be around 25L because that provided adequate sensitivity in combination with a reasonable sampling time and flow rate. Sampling time was also able to be shortened to 120-minute sample periods with a flow of 200mL/min for a sample volume of 24L which allows for multiple sample periods during a day. This sampling method provided adequate sensitivity for most but not all terpenes collected in ambient samples, many of the terpenes were potentially present below the limits of detection for analysis.

Our results indicate that there is so much farther to delve into studies revolving around different terpene concentrations to further develop if there are different terpene profiles that can be established for different locations or during different weather events. This also includes the potential for studies that specifically assess if there are different terpene profiles present outside of cannabis growing facilities, since in this preliminary study the terpene profile concentrations that were outside the cannabis facilities were more similar to forest and urban park terpene profiles than they were to the terpene profiles inside the cannabis facilities. The terpenes in highest abundance for outdoor forest environments were α-pinene,

followed by β-pinene, d-limonene, borneol, 3-carene among others in lower concentrations. The terpenes that were most abundant inside cannabis facilities were β-myrcene followed by smaller concentrations of α-pinene, β-pinene, and limonene. The results found in this preliminary study help to form the basis for further studies of terpenes in cannabis facilities as well as studies of health outcomes in relation to forest bathing and cannabis workers' health.

Appendices

Appendix I – Standard Operating Procedures for sampling

Locations

Hamlin Park-16006 15th Ave NE, Shoreline, WA 98155

Cannabis Facility #1- Seattle WA

Maple Leaf Reservoir Park -1020 NE 82nd St, Seattle, WA 98115

Cannabis Facility #2-Seattle WA

Arboretum -2300 Arboretum Dr E, Seattle, WA 98112

Dates

Phase 1:

12/7/21- Hamlin Park -all day

1/11/22- Cannabis Facility #1- all day

Phase 2:

Table I-1. Phase 2 Terpene Sampling Dates and Locations, with number of samples collected at each location

Date	**Approx Time (24hr)**	**Duration(hr)**	**Location**	**Notes**
5/12/22	12:00	2	Hamlin Park	2 samples +FB
5/13/22	7:00	2	Maple Leaf	3 samples
	10:00	2	Hamlin Park	2 samples
	13:00	2	Arboretum	3 samples
5/14/22	8:30	2	Maple Leaf	3 samples
	11:00	2	Arboretum	2 samples +FB
5/16/22	12:00	2	Cannabis Facility #2	2 samples
5/17/22	9:00	2	Cannabis Facility #2	3 samples
5/18/22	15:00	2	Cannabis Facility #1	3 samples +FB
5/19/22	12:00	2	Cannabis Facility #1	3 samples

Timeline

Materials List for Field Collection

- Sorbent tubes
- Gilian GilAir Plus sampling pumps
- DryCal Calibration Device
- Sorbent tube blank for calibration
- Tubing
- Sorbent tube connections
- Washer fittings
- One stand/box combo
- Foil for protection from light and external exposures
- Data logging sheet
- Labels for tubes
- Pen/sharpie
- Umbrella
- Charged phone/timer

Equipment Procedures

Equipment Information

Sampling Pumps

Pump Type	Pump ID	S/N	Notes
Gilian GilAir Plus Pump	TL1	20181120117	Blue Teaching Lab pump
Gilian GilAir Plus Pump	TL2	20181120119	Blue Teaching Lab pump
Gilian GilAir Plus Pump	TL3	20181120120	Blue Teaching Lab pump
Gilian GilAir Plus Pump	TL4	20181120118	Blue Teaching Lab pump
Gilian GilAir Plus Pump	TL5	20190220121	Blue Teaching Lab pump

Calibration Equipment

Name	Device	S/N	Notes
Calibration Pump	DryCal Defender 510	118775	low flow 5-500ml/min
Calibration Tube	TD tube Glass CT T420	A082511	Tube Used for all pump calibration

Field Data Log Example

Field Log Example

Date:_____ Location: _____

Time_____ Temperature:_____ Relative humidity: _____ Pressure: _____

Sample ID	Tube S/N	Pump ID	Initial Flow	Start Time	Final Flow	Stop Time	Time Sampled
UW###							
UW###							
UW###							

Notes: _____

Appendix II- Methods-Supplementary tables and figures

Phase 1:

Table II-1. The weather data recorded at the start and the end of sampling at Hamlin Park on 12/7/21

Hamlin Park	**Time (24hr)**	**Temperature (°F)**	**Pressure (hPa)**	**Relative humidity(%)**
Start	8:35	44	1014	100
Finish	17:00	47	1016	96

Figure II-1.Hamlin Park Location Morning Fog 12/7/21

Figure II-2. Location of Air Sampling Set Up at Hamlin Park 12/7/21

Figure II-3. Air Sampling System set up Hamlin Park 12/7/21

Figure II-4. Blue GilAir Plus Sampling pump at 200mL/min

Table II-2. Temperature, Pressure, and Relative humidity for the three sample locations at Cannabis Facility #1 1/11/22

Sample Location #	**1**	**2**	**3**
Time	10:05	12:37	17:03
Location	Grow Room #6	Trim Room	Outside Facility
Temp (°F)	76.8	67.8	51
Pressure (hPa)	1024	1023	1023
Relative humidity (%)	51.1	53.4	93

Figure II-5. Grow Room cannabis air sampling at Cannabis Facility #1 1/11/22

Figure II-6. Density of grow room at Cannabis Facility #1 1/11/22

Figure II-7. Trim Room air sampling location set-up, Cannabis Facility #1 1/11/22

Figure II-8. Outdoor air sampling location Cannabis Facility #1 1/11/22

Phase 2:

Table II-3. Weather Data for all locations during phase 2

Date	Location	Time(24 hr)	Temp (°F)	Relative humidity (%)	Pressure (hPa)	Wind (mph)	Wind Direction	Conditions
5/12/22	Hamlin Park	13:29	48	81	1015	10	SSE	heavy Rain whole sample period
5/13/22	Maple Leaf Reservoir	7:27	45	75	1024	9	SSW	Sunny with clouds
5/13/22	Hamlin Park	10:02	47	68	1024	8	SSW	Sun breaks, cloudy
5/13/22	Arboretum	13:06	54	53	1024	7	N	Sunny with some clouds
5/14/22	Maple Leaf Reservoir	8:30	48	83	1015	No Wind	N/A	Overcast with rain showers
5/14/22	Arboretum	12:30	55	75	1016	9	SE	Overcast with sun breaks
5/16/22	Cannabis Facility #2	12:02	51	77	1020	8	NNE	Sunny with some clouds
5/17/22	Cannabis Facility #2	9:35	47	80	1025	8	SSE	Overcast with rain showers
5/18/22	Cannabis Facility #1	12:58	55	77	1017	21	S	Sunny with some clouds, very windy
5/19/22	Cannabis Facility #1	10:03	48	71	1022	8	S	cloudy with few sun breaks

Figure II-9. Maple leaf Reservoir Park 5/13/22

Figure II-10. Maple leaf Reservoir Park Air sampling set up 5/13/22

Figure II-11. Maple Leaf Reservoir Park air sampling 5/14/22

Figure II-12. Arboretum air sampling set up 5/14/22

Figure II-13. Hamlin Park air sampling set up 5/13/22

Figure II-14. Cannabis Facility #2, back of building air sampling from car window 5/16/22

Figure II-15. Cannabis Facility # 2, front of building air sampling from car window 5/17/22

Figure II-16. Cannabis Facility #1 air sampling set up outside door 5/18/22

Figure II-17. Cannabis Facility #1 air sampling set up outside door 5/19/22

Table II-4. Phase II samples identification and location of sample

Sample Tube ID	S/N	Notes
Calibration	A082511	Calibration Tube Used
UW100	A079092	Field Blank (FB)
UW101	A079085	Hamlin Park
UW102	A079361	Hamlin Park
UW103	A079079	Maple Leaf Reservoir
UW104	A079354	Maple Leaf Reservoir
UW105	A079078	Maple Leaf Reservoir
UW106	A079096	Hamlin Park
UW107	A079306	Hamlin Park
UW108	A079311	Arboretum
UW109	A079309	Arboretum
UW110	A079319	Arboretum
UW111	A079312	Maple Leaf Reservoir
UW112	A079077	Maple Leaf Reservoir
UW113	A079318	Maple Leaf Reservoir
UW114	A079322	Arboretum
UW115	A079099	Arboretum
UW116	A079098	Arb-Field Blank

UW117	A082489	Cannabis Facility 2
UW118	A082555	Cannabis Facility 2
UW119	A082523	Cannabis Facility 2
UW120	A083137	Cannabis Facility 2
UW121	A079094	Cannabis Facility 2
UW122	A082568	Cannabis Facility 1
UW123	A082532	Cannabis Facility 1
UW124	A082549	Cannabis Facility 1
UW125	A079088	Cannabis Facility 1-FB
UW126	A082528	Cannabis Facility 1
UW127	A079307	Cannabis Facility 1
UW128	A082567	Cannabis Facility 1

Figure II-18. Parameters of the thermal desorption process from Millipore/Sigma, used for phase 1 samples

Appendix 3- Results -Supplementary tables and figures

Phase 1: Hamlin Park 12/7/21

Table III-1. Results from Terpene sampling measured in ug/m^3 Hamlin Park 12/7/21

Tube Type	**Glass CT T420**	**Glass CT T420**	**SS CT T420**	**SS CT T420**	**Glass Tenax®**	**Glass Tenax®**	**Glass CT T420**	**Glass CT T420**
Sample ID	UW01	UW02	UW03	UW04	UW05	UW06	UW07	UW08
Sample Volume (L)	25.5	98.9	99.6	80.6	99.8	83.1	Blank	Blank
α-Pinene	0.282	0.183	0.036	0.044	0.107	0.116	0.0	0.0
Camphene	0.091	0.061	0.064	0.054	0.036	0.038	0.0	0.0
β-Pinene	0.115	0.071	0.018	0.029	0.025	0.025	0.0	0.0
p-Cymene	0.078	0.054	0.066	0.058	0.048	0.044	0.0	0.0
d-Limonene	0.118	0.074	0.068	0.071	0.033	0.026	0.0	0.0
Camphor	0.033	0.015	0.014	0.014	0.017	0.016	0.0	0.0

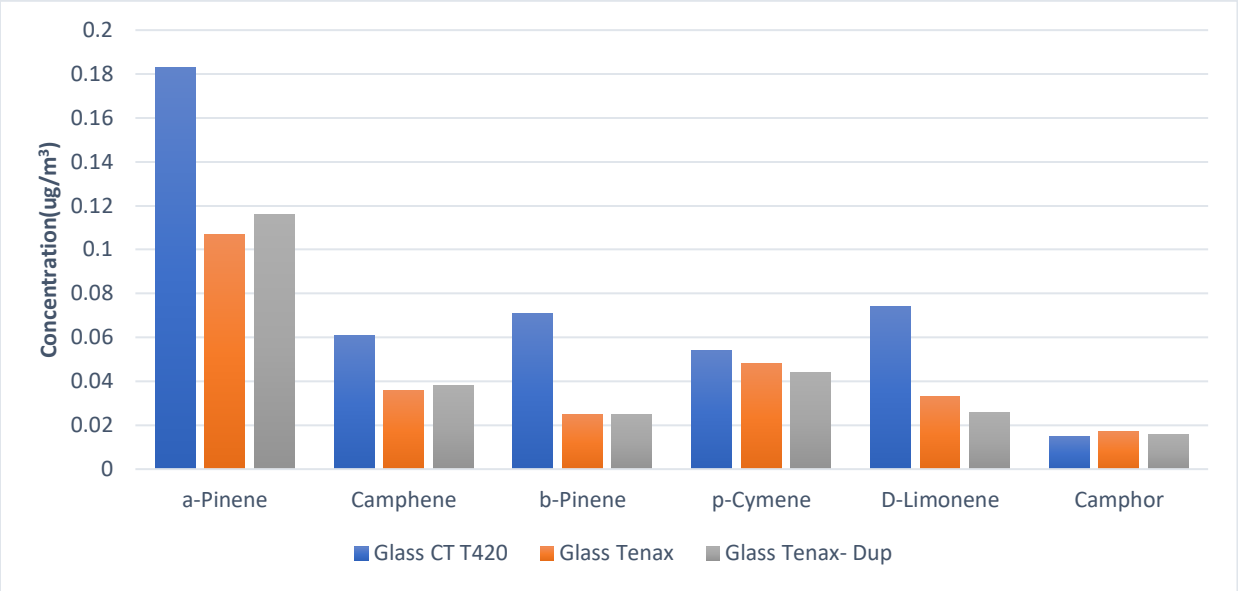

Figure III-1. Hamlin Park 12/7/21 Glass CT T420 vs Glass Tenax® terpene concentrations(µg/m³). 100L nominal samples volumes.

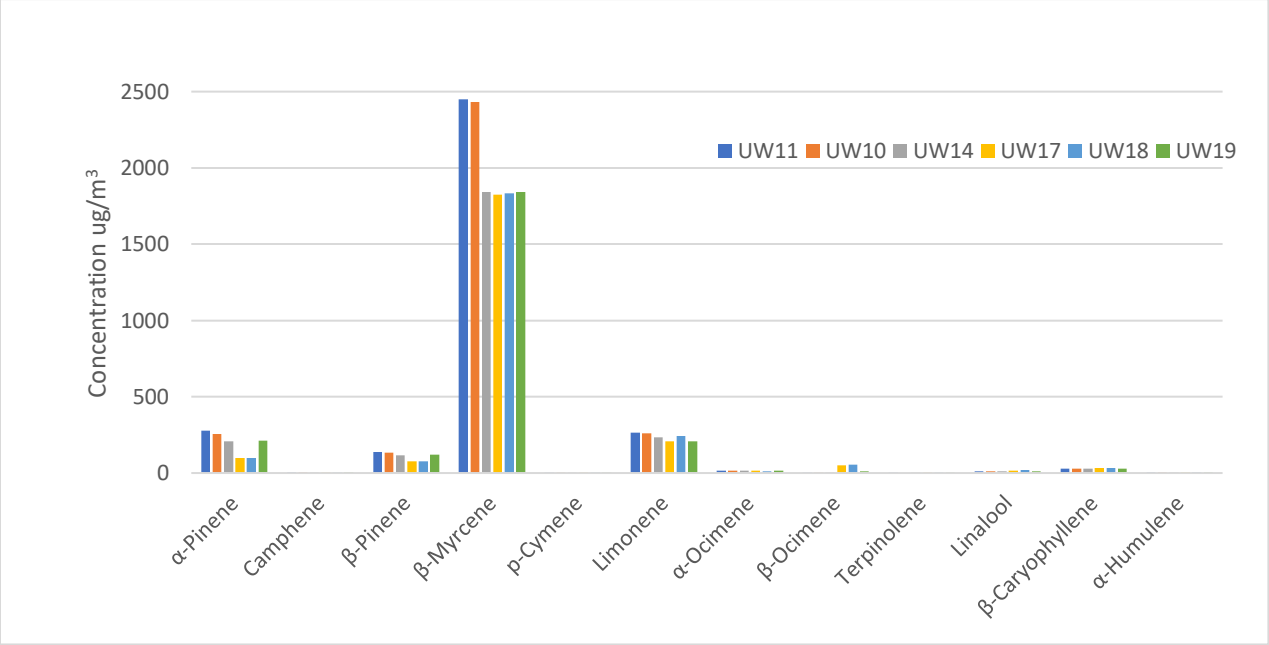

Figure III-2. Cannabis Facility #1 Terpene concentrations for all samples taken in Grow room on 1/11/22

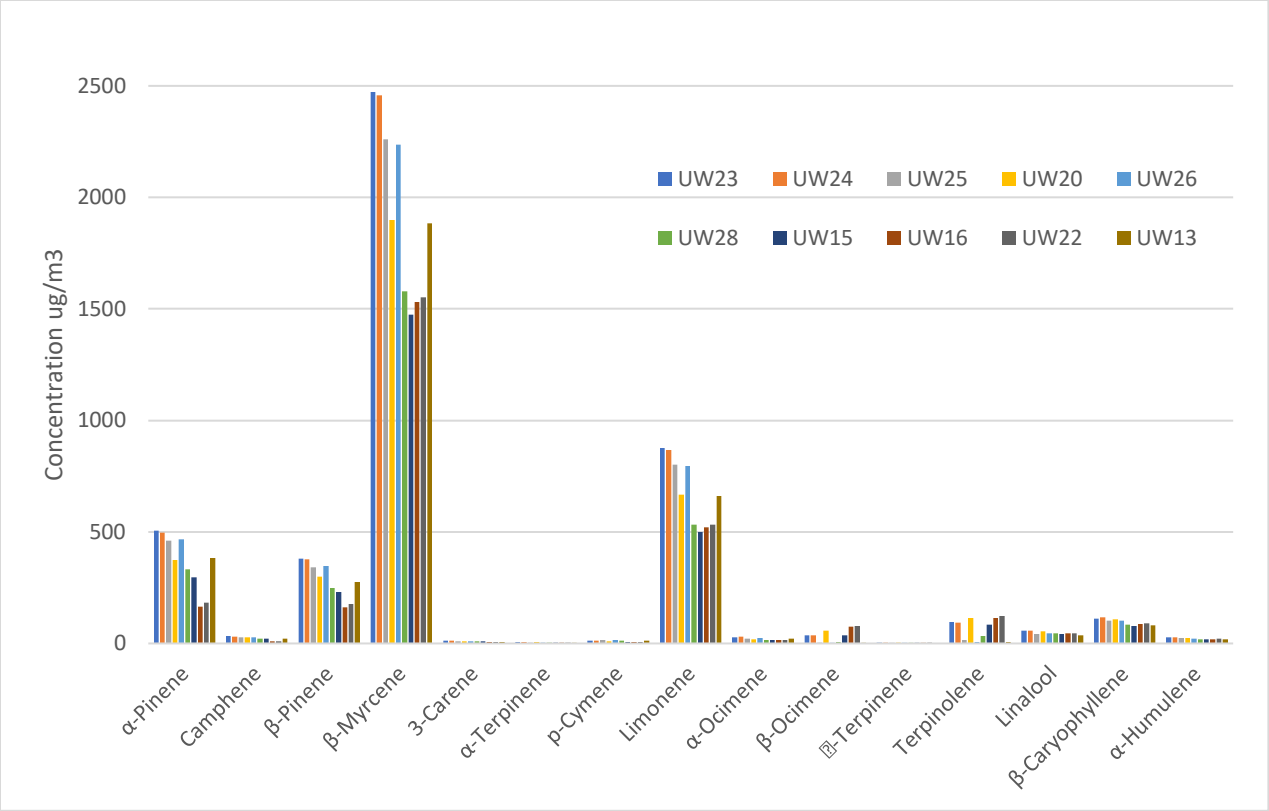

Figure III-3. Cannabis Facility #1 Terpene concentrations for all samples taken in Trim room on 1/11/22

Table III-2. Cannabis Facility #1 Average Indoor Terpene Concentration µg/m³ 1/11/21

Terpene	Grow Room Average	Trim Room Average
α-Pinene	238.1	414.8
Camphene	5.25	26.5
β-Pinene	126.8	312.55
β-Myrcene	2140.55	2033.1875
3-Carene	N.D.	9.975
α-Terpinene	N.D.	4.5625
p-Cymene	1.9	11.95
Limonene	240.825	712.8
α-Ocimene	14.375	22.1875
β-Ocimene	5.3	22.4375
g-Terpinene	N.D.	2.5875
Terpinolene	0.975	56.1875
Linalool	11.05	47.8875
β-Caryophyllene	29.25	98.1625
α-Humulene	7.2	22.7875

Phase 2 Results

Table III-3 Field Blank Results $\mu g/m^3$

UW ID		Camphene	3-Carene	Fenchol	4-Isopropyltol	D-Limonene	beta-Myrcene	alpha-Pinene	beta-Pinene	alpha-Terpineol
UW100 FB	Result (ug/m3)	0.045	0.139	0.095	0.096	0.378	0.052	0.147	0.123	0.047
UW116 FB	Result (ug/m3)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UW125 FB	Result (ug/m3)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mean		0.015	0.046	0.032	0.032	0.126	0.017	0.049	0.041	0.016
SD		0.02598076	0.08010735	0.05484828	0.05556996	0.21819029	0.03007033	0.08467804	0.07120653	0.02694301
Range		173%	173%	173%	173%	173%	173%	173%	173%	173%

Table III-4 Lab and Field Blanks with Reporting Limits in $\mu g/m^3$

	Lab Blank ug/m3	Lab Blank RL (ug/m3)	UW100-FB Result (ug/m3)	UW100-FB RL(ug/m3)	UW116-FB Result (ug/m3)	UW116-FB RL(ug/m3)	UW125-FB Result (ug/m3)	UW125-FB RL(ug/m3)
Borneol	0.0000	0.0417	0.000	0.417	0.000	0.042	0.000	0.042
Camphene	0.0000	0.0104	0.045	0.042	0.000	0.010	0.000	0.010
Camphor	0.0000	0.0208	0.000	0.083	0.000	0.021	0.000	0.021
3-Carene	0.0000	0.0208	0.139	0.083	0.000	0.021	0.000	0.021
beta-Caryophyllene	0.0154	0.0104	0.000	0.000	0.000	0.010	0.000	0.010
alpha-Cedrene	0.0000	0.0104	0.000	0.000	0.000	0.010	0.000	0.010
Cedrol	0.0000	0.0417	0.000	0.042	0.000	0.042	0.000	0.042
Fenchol	0.0000	0.0104	0.095	0.042	0.000	0.010	0.000	0.010
Fenchone	0.0000	0.0104	0.000	0.042	0.000	0.010	0.000	0.010
Geranyl Acetate	0.0000	0.0208	0.000	0.167	0.000	0.021	0.000	0.021
alpha-Humulene	0.0433	0.0104	0.000	0.167	0.000	0.010	0.000	0.010
Isoborneol	0.0000	0.0417	0.000	0.417	0.000	0.042	0.000	0.042
4-Isopropyltoluene (p-	0.0000	0.0104	0.096	0.042	0.000	0.010	0.000	0.010
D-Limonene	0.0000	0.0208	0.378	0.083	0.000	0.021	0.000	0.021
Linalool	0.0000	0.0104	0.000	8.792	0.000	0.310	0.000	0.112
DL-Menthol	0.0000	0.0417	0.000	0.167	0.000	0.042	0.000	0.042
beta-Myrcene	0.0004	0.0104	0.052	0.042	0.000	0.010	0.000	0.010
alpha-Pinene	0.0000	0.0104	0.147	0.042	0.000	0.010	0.000	0.010
beta-Pinene	0.0000	0.0208	0.123	0.083	0.000	0.021	0.000	0.021
Pulegone	0.0000	0.0104	0.000	0.167	0.000	0.010	0.000	0.010
alpha-Terpinene	0.0000	0.0104	0.000	0.042	0.000	0.010	0.000	0.010
gamma-Terpinene	0.0000	0.0104	0.000	0.042	0.000	0.010	0.000	0.010
alpha-Terpineol	0.0029	0.0104	0.047	0.042	0.000	0.010	0.000	0.010
Terpinolene	0.0000	0.0104	0.000	0.042	0.000	0.010	0.000	0.010

Table III-5 Forest environment terpene concentrations found $\mu g/m^3$ N.T. =specific terpene was not tested

Location	UW ID	Sample Volume(L)	Borneol	Camphene	Camphor	3-Carene	beta-Caryophyllene	Fenchol	Fenchone	alpha-Humulene	4-Isopropyltoluene (p-Cymene)	D-Limonene	DL-Menthol	beta-Myrcene	alpha-Pinene	beta-Pinene	alpha-Terpineol
Hamlin Park	UW101	24.069	0.234	0.178	0.111	0.207	N.T.	0.156	0.053	<0.118	0.173	0.499	0.183	0.052	1.263	0.569	<0.029
Hamlin Park	UW102	24.043	<0.294	0.104	<0.059	0.169	N.T.	0.064	<0.029	<0.118	0.149	0.474	<0.118	0.046	1.244	0.611	<0.029
Hamlin Park	UW106	23.933	<0.030	0.034	0.032	<0.015	<0.007	<0.007	0.031	0.011	0.020	<0.015	<0.030	<0.007	<0.007	<0.015	<0.007
Hamlin Park	UW107	23.949	<0.030	<0.007	<0.015	<0.015	<0.007	<0.007	<0.007	<0.007	<0.007	<0.015	<0.030	<0.007	<0.007	<0.015	<0.007
		Mean	0.147	0.081	0.054	0.101	0.004	0.059	0.030	0.063	0.087	0.251	0.090	0.028	0.630	0.303	0.018
		SD	0.138	0.076	0.042	0.101	0.004	0.070	0.019	0.063	0.086	0.272	0.075	0.024	0.719	0.333	0.013
		Range	94%	95%	78%	100%	115%	120%	62%	99%	98%	109%	83%	86%	114%	110%	69%
Maple Leaf	UW103	23.894	<0.030	0.054	0.024	<0.015	0.012	<0.007	0.020	<0.007	0.033	<0.015	<0.030	<0.007	<0.007	<0.015	<0.007
Maple Leaf	UW104	23.970	<0.029	0.055	0.041	<0.015	<0.007	0.019	0.036	<0.007	0.039	<0.015	<0.029	<0.007	<0.007	<0.015	<0.007
Maple Leaf	UW105	24.031	<0.029	0.023	0.031	<0.015	<0.007	<0.007	0.015	<0.007	0.023	<0.015	<0.029	<0.007	<0.007	<0.015	<0.007
Maple Leaf	UW111	24.000	<0.029	0.068	<0.015	0.026	<0.007	<0.007	<0.007	<0.007	0.043	0.038	<0.029	<0.007	0.313	0.211	<0.007
Maple Leaf	UW112	23.910	<0.030	0.072	<0.015	0.045	<0.007	0.015	<0.007	<0.007	0.061	0.079	<0.030	<0.007	0.448	0.337	<0.007
Maple Leaf	UW113	23.890	<0.030	0.052	<0.015	<0.015	<0.007	0.014	<0.007	<0.007	0.042	<0.015	<0.030	<0.007	0.106	0.133	<0.007
		Mean	0.030	0.054	0.023	0.022	0.008	0.012	0.015	0.007	0.040	0.029	0.030	0.007	0.148	0.121	0.007
		SD	0.000	0.017	0.011	0.012	0.002	0.005	0.011	0.000	0.013	0.026	0.000	0.000	0.189	0.133	0.000
		Range	0%	32%	47%	56%	22%	42%	73%	0%	31%	89%	0%	0%	127%	110%	0%
Arboretum	UW108	23.940	<0.030	<0.007	<0.015	<0.015	<0.007	<0.007	<0.007	<0.007	0.025	0.041	<0.030	<0.007	0.015	<0.015	<0.007
Arboretum	UW109	23.992	<0.029	0.011	<0.015	<0.015	<0.007	<0.007	<0.007	<0.007	0.015	<0.015	<0.029	<0.007	<0.007	<0.015	<0.007
Arboretum	UW110	23.986	<0.029	<0.007	<0.015	<0.015	<0.007	<0.007	<0.007	<0.007	<0.007	0.023	0.044	<0.007	<0.007	<0.015	<0.007
Arboretum	UW114	23.929	<0.030	0.097	0.034	0.079	<0.007	0.033	0.019	<0.007	0.119	0.325	<0.030	0.011	0.330	0.162	<0.007
Arboretum	UW115	23.880	<0.030	0.107	0.038	0.093	<0.007	0.037	0.028	<0.007	0.116	0.358	<0.030	0.014	0.370	0.209	<0.007
		Mean	0.0295	0.0458	0.0233	0.0434	0.0074	0.0184	0.0137	0.0074	0.0566	0.1522	0.0325	0.0094	0.1461	0.0830	0.0074
		SD	0.0001	0.0512	0.0118	0.0396	0.0000	0.0152	0.0092	0.0000	0.0558	0.1734	0.0066	0.0030	0.1868	0.0949	0.0000
		Range	0%	112%	51%	91%	0%	83%	67%	0%	99%	114%	20%	31%	128%	114%	0%

Table III-6 Cannabis Facilities terpene concentrations $\mu g/m^3$

Location	UW ID	Sample Volume (L)	Borneol	Camphene	Camphor	3-Carene	Fenchol	Fenchone	Geranyl Acetate	4-Isopropyltoluene (p-Cymene)	D-Limonene	DL-Menthol	beta-Myrcene	alpha-Pinene	beta-Pinene	alpha-Terpinene	alpha-Terpineol
Cannabis Facility #2	UW117	23.954	<0.030	0.018	<0.015	<0.015	<0.007	<0.007	0.102	0.027	0.109	<0.030	<0.007	0.400	0.060	<0.007	<0.007
Cannabis Facility #2	UW118	23.943	<0.030	0.025	<0.015	<0.015	<0.007	<0.007	0.119	0.028	0.126	<0.030	<0.007	0.455	0.075	<0.007	<0.007
Cannabis Facility #2	UW119	23.920	0.088	0.158	0.069	0.134	0.094	<0.007	0.202	0.196	1.827	0.249	<0.007	1.885	0.627	0.012	<0.007
Cannabis Facility #2	UW120	23.916	0.058	0.179	0.074	0.139	0.096	<0.007	0.172	0.206	1.777	0.288	<0.007	1.501	0.598	0.018	<0.007
Cannabis Facility #2	UW121	23.949	0.291	0.310	0.116	0.323	0.155	0.020	0.209	0.412	3.608	0.710	0.063	1.808	0.889	0.030	0.626
		Mean	0.099	0.138	0.058	0.125	0.072	0.010	0.161	0.174	1.489	0.261	0.019	1.210	0.450	0.015	0.131
		SD	0.110	0.121	0.043	0.126	0.064	0.006	0.048	0.159	1.453	0.278	0.025	0.729	0.367	0.010	0.277
		Range	111%	88%	75%	101%	89%	57%	30%	91%	98%	107%	135%	60%	82%	64%	211%
Cannabis Facility #1	UW122	23.994	<0.029	<0.007	<0.015	<0.015	<0.007	<0.007	<0.015	<0.007	<0.015	<0.029	<0.007	0.106	<0.015	<0.007	<0.007
Cannabis Facility #1	UW123	24.175	<0.029	<0.007	<0.015	<0.015	<0.007	<0.007	<0.015	<0.007	0.053	<0.029	<0.007	0.339	0.029	<0.007	<0.007
Cannabis Facility #1	UW124	23.913	<0.030	0.020	<0.015	<0.015	<0.007	<0.007	<0.015	0.012	0.123	<0.030	<0.007	0.740	0.084	<0.007	<0.007
Cannabis Facility #1	UW126	24.363	<0.029	<0.007	<0.015	<0.015	<0.007	<0.007	<0.015	0.014	0.083	<0.029	<0.007	0.065	0.024	<0.007	<0.007
Cannabis Facility #1	UW127	24.424	<0.029	0.033	0.021	<0.014	0.023	0.018	<0.014	0.037	0.135	<0.029	<0.007	<0.007	<0.014	<0.007	<0.007
Cannabis Facility #1	UW128	23.864	<0.030	0.026	<0.015	<0.015	0.012	<0.007	<0.015	0.018	0.137	<0.030	<0.007	0.578	0.080	<0.007	<0.007
		Mean	0.029	0.017	0.016	0.015	0.011	0.009	0.015	0.016	0.091	0.029	0.007	0.306	0.041	0.007	0.007
		SD	0.000	0.011	0.003	0.000	0.006	0.004	0.000	0.011	0.050	0.000	0.000	0.300	0.032	0.000	0.000
		Range	1%	66%	16%	1%	58%	46%	1%	70%	55%	1%	1%	98%	79%	1%	1%

Table III-7 Reporting Limits using Sample Volume(L) listed for all Phase 2 Data µg/m^3

Location	Hamlin Park-FB	Hamlin Park	Hamlin Park	Maple Leaf	Maple Leaf	Maple Leaf	Hamlin Park	Hamlin Park	Arboretum	Arboretum	Arboretum	Maple Leaf	Maple Leaf	Maple Leaf	Arboretum	Arboretum	Arboretum-FB	Cannabis Facility #2	Cannabis Facility #2	Cannabis Facility #2	Cannabis Facility #2	Cannabis Facility #2	Cannabis Facility #1	Cannabis Facility #1	Cannabis Facility #1	Cannabis Facility #1-FB	Cannabis Facility #1	Cannabis Facility #1	Cannabis Facility #1
UW ID	UW100	UW101	UW102	UW103	UW104	UW105	UW106	UW107	UW108	UW109	UW110	UW111	UW112	UW113	UW114	UW115	UW116	UW117	UW118	UW119	UW120	UW121	UW122	UW123	UW124	UW125	UW126	UW127	UW128
Sample Volume(L)	24.0	24.1	24.0	23.9	24.0	24.0	23.9	23.9	23.9	24.0	24.0	24.0	23.9	23.9	23.9	23.9	24.0	24.0	23.9	23.9	23.9	23.9	24.0	24.2	23.9	24.0	24.4	24.4	23.9
Borneol	0.417	0.166	0.416	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.041	0.042	0.042	0.041	0.041	0.042
Camphene	0.042	0.042	0.042	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Camphor	0.083	0.083	0.083	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.020	0.021
3-Carene	0.083	0.083	0.083	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.020	0.021
beta-Caryophyllene	0.000	0.000	0.000	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
alpha-Cedrene	0.000	0.000	0.000	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Cedrol	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.041	0.042	0.042	0.041	0.041	0.042
Fenchol	0.042	0.042	0.042	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Fenchone	0.042	0.042	0.042	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Geranyl Acetate	0.167	0.166	0.166	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.020	0.021
alpha-Humulene	0.167	0.166	0.166	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Isoborneol	0.417	0.415	0.416	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.041	0.042	0.042	0.041	0.041	0.042
4-Isopropyltoluene (p-Cymene)	0.042	0.042	0.042	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
D-Limonene	0.083	0.083	0.083	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.020	0.021
Linalool	8.792	7.271	8.693	0.296	0.114	0.092	0.217	0.576	0.977	0.233	0.028	0.471	0.540	0.201	11.576	26.089	0.310	0.184	0.271	0.932	0.828	13.028	0.083	0.070	0.124	0.112	0.090	0.131	0.134
DL-Menthol	0.167	0.166	0.166	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.041	0.042	0.042	0.041	0.041	0.042
beta-Myrcene	0.042	0.042	0.042	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
alpha-Pinene	0.042	0.042	0.042	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
beta-Pinene	0.083	0.083	0.083	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.020	0.021
Pulegone	0.167	0.042	0.042	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
alpha-Terpinene	0.042	0.042	0.042	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
gamma-Terpinene	0.042	0.042	0.042	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
alpha-Terpineol	0.042	0.042	0.042	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Terpinolene	0.042	0.042	0.042	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010

Table III-8. Two sample T-test results for outdoor forest environment samples

Two sample T-test (α-pinene)	T value	Degrees of Freedom	p-value	Mean(μg/m^3)	95% CI
Arboretum	-1.3144	3.3252	0.2729	0.146	(-1.59,0.628)
Hamlin Park				0.63	
Two sample T-test (α-pinene)	T value	Degrees of Freedom	p-value	Mean(μg/m^3)	95% CI
Hamlin Park	1.311	3.277	0.2741	0.63	(-0.634,1.598)
Maple Leaf				0.148	
Two sample T-test (α-pinene)	T value	Degrees of Freedom	p-value	Mean(μg/m^3)	95% CI
Arboretum	-0.0172	8.67	0.9866	0.146	(-0.26,0.25)
Maple Leaf				0.148	

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