# Odor and Emissions Analysis from Marijuana Grow Farms

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## Introduction

The Spokane Clean Air Agency has received odor complaints from residents living near marijuana growing facilities in Spokane, WA. It is hypothesized the odor is caused by various terpenes emitted by marijuana, but, the specific component that causes its distinct odor has not yet been identified. Facilities also use pesticides and cleaning agents which may be contributing to the odor complaints.

In order to construct a complete emissions profile on indoor marijuana growing operations, both plant-based and facility-based emissions were considered in this study. Emission rates can be calculated and used to model facility emissions, and determine how far smells can potentially travel. Since many of the compounds released are terpenes and other volatile organic compounds (VOCs), there are many further environmental applications of this research.

**Goals:**

- Determine major odor constituents of marijuana growing operations
- Construct emissions inventory for a typical indoor growing facility
- Calculate emission rates for compounds leaving facilities
- Determine possible distances odor can travel

**Image 1:** Grow Op Farms tending to marijuana plants in their growing room. *(Marijuana Venture/David Muret)*

## Methods

**Facility Samples:**

- Air samples were collected by the Spokane Clean Air Agency and sent to Washington State University.
- Twenty samples were taken from four facilities throughout Spokane: Grow Op Farms (8 samples), FARi (2 samples), Root Down (6 samples), and Seven Blade NW (4 samples).

**Headspace Samples:**

- Headspace of two marijuana products were analyzed to distinguish between plant based emissions and facility based emissions

**Analysis:**

- Air canisters and bottles were analyzed using gas chromatography-mass spectrometry (GC-MS).
- Compounds without standards were identified via their mass spectrum results using the NIST database

**Emissions Inventory:**

- Grow Op Farms was chosen to create the emissions inventory for a typical grow operation due to their size and high regulation of the operation.
- Compounds that were in 6 of the 8 samples were listed in the emissions inventory.
- Categorized as plant-based vs. facility based using headspace results

**Emissions Rate:**

- Calculated using steady-state box model with Root Down air exhaust rates and in-facility terpene concentrations
- Daytime lifetimes were calculated using known rate constants, and average O3 and HO day time concentrations

## Results and Data

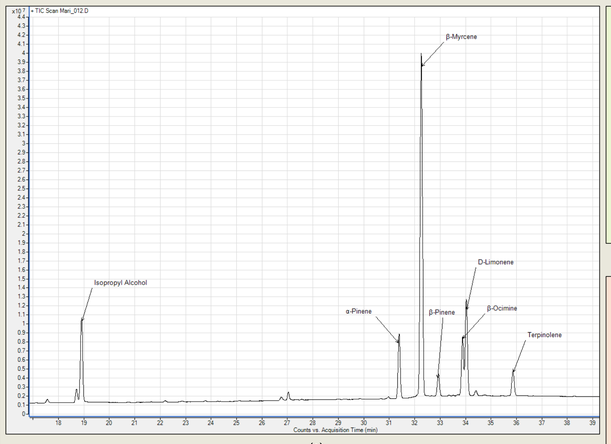
### Grow Op Farms Emissions Inventory

| Plant-Based Emissions |
|---|
| 3-Carene |
| D-Limonene |
| m-Cymenene |
| Terpinolene |
| α-Phellandrene |
| α-Pinene |
| β-Myrcene |
| β-Ocimene |
| β-Phellandrene |
| β-Pinene |

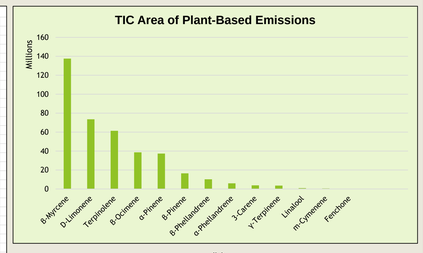
| Facility-based Emissions |
|---|
| 2-Butenoic acid, 3-methyl-, methyl ester |
| 1,3-Pentadiene |
| 2-Propanol, 2-methyl- |
| Acetic acid, hexyl ester |
| Acetone |
| Butanenitrile, 2-methyl- |
| Butanoic acid, methyl ester |
| Ethanol |
| Ethyl Acetate |
| Hexanal |
| Isopropyl acetate |
| Isopropyl Alcohol |
| Isopropyl butyrate |
| Propanoic acid, ethyl ester |
| Tetrahydrofuran |
| Trichloromonofluoromethane |

**Figure 1:** Emissions inventory for Grow Op Farms. Includes compounds found in over 75% of samples that are divided into plant-based (present due to marijuana plant emissions) and facility-based (present due to facility related activities such as cleaning, pesticides, etc.)

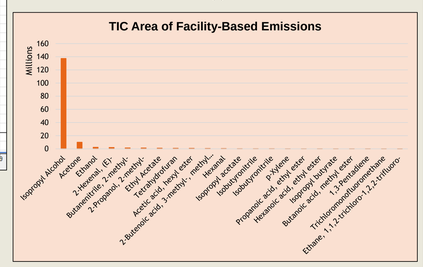
### Chromatogram Findings




(a)



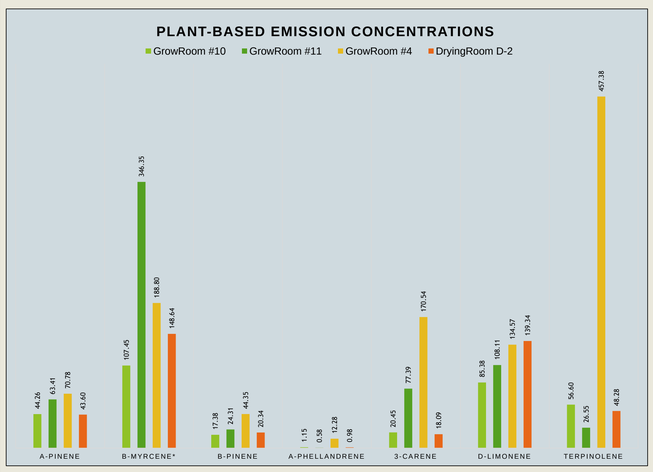

(b)




(c)

**Figure 2:** (a) shows sample chromatogram with labeled peaks, (b) TIC area of plant-based emissions to show relative abundance of each compound (c) TIC area of facility-based emissions to show relative abundance in comparison to plant-based. For (b) and (c), all possible constituents are included, not just those included in emissions inventory.

### Concentrations and Emission Rates




(a)

| Emission Rates | |
|---|---|
| **Compound** | **Source Emission Rate (mg/hr)** |
| a-Pinene | 4.818 |
| | |
| b-Myrcene | 116.340 |
| | |
| b-Pinene | 3.501 |
| | |
| a-Phellandrene | 0.206 |
| | |
| 3-Carene | 0.494 |
| | |
| D-Limonene | 44.106 |
| | |
| Terpenoline | 0.782 |

(b)

**Figure 3:** (a) Details mean concentrations of plant-based emissions in ppbv for Grow Op Farms. (b) Provides emission rates for plant-based emissions in mg/hr using concentrations and air flow from Root Down farms as air flow rates were not given for Grow Op Farms. * = Retention factor for b-Pinene used

## Results and Data cont.

### Daytime Terpene Lifetime

| Compound | HO Rate | O3 Rate | Lifetime (min) |
|---|---|---|---|
| 3-Carene | 8.80E-11 | 3.70E-17 | 43.870 |
| Caryophyllene | 1.97E-10 | 1.20E-14 | 1.075 |
| D-Limonene | 1.70E-10 | 2.01E-16 | 18.659 |
| Terpinolene | 2.25E-10 | 1.88E-15 | 5.262 |
| α-Phellandrene | 3.13E-10 | 2.98E-15 | 3.433 |
| α-Pinene | 5.37E-11 | 9.71E-17 | 51.521 |
| ß-Myrcene | 2.15E-10 | 4.74E-16 | 11.905 |
| ß-Ocimene | 2.52E-10 | 5.44E-16 | 10.246 |
| ß-Phellandrene | 1.68E-10 | 4.71E-17 | 23.935 |
| ß-Pinene | 7.89E-11 | 1.64E-17 | 52.085 |

**Figure 4:** Reaction rates (molecules/cm$^3$ S) due to HO and O3, and corresponding lifetimes (min) for daytime activity. Lifetimes can help indicate how far a compound can travel. Given these lifetimes, odor has the ability to travel a decent ways before it completely degrades.

## Discussion

Through this research, an emissions inventory was created and emission rates for the primary odor components were calculated. The most abundant emissions from production facilities are isopropyl alcohol, β-Myrcene, D-Limonene, α-Pinene, β-Pinene, Terpinolene and β-Ocimene. Caryophyllene was also present in select samples and the headspace data, however, the GC-MS run time was not long enough for it to consistently appear. The presence of isopropyl alcohol is due to its use as a cleaning agent throughout the facilities.

Due to terpenes strong odor, it is highly probable the combination of the various terpenes is responsible for the odor of marijuana. The daytime terpene lifetimes indicate compounds can potentially travel a few miles before complete degradation, which is far enough to enter nearby neighborhoods and impact residents.

## Further Research

Further investigations are necessary in order to fully understand odor and emissions from marijuana grow farms.

- Acquire standards to determine concentrations of other abundant compounds
- Have longer GC-MS run time to capture possible sesquiterpenes
- Create synthetic terpene combinations to determine what causes marijuana odor
- Model emissions from facilities to determine a more accurate distance odor can travel
- Conduct further and more controlled studies to thoroughly determine plant-based and facility-based emissions

**Image 2**: Marijuana grow farms. *(AFP Photo/Brendan Smialowski)*

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