Impacts of the Legalization of Marijuana on Emissions and Air Quality in US

Kirsti Ashworth[1] and Christine Wiedinmyer[2]
[1]University of Michigan, [2]National Center for Atmospheric Research

1. INTRODUCTION

Recent changes in US state regulations allow for legal marijuana cultivation facilities (MCFs, Figure 1) and use in Colorado and Washington. Marijuana plants (*Cannabis spp.*) emit primarily biological particles (e.g., Fungi, Pollen [1, 2]) and a host of biogenic volatile organic compounds (VOCs). The emissions, however, are very uncertain and are not well constrained. We hypothesize that, as the number of MCFs increase across these states, particularly in and near urban areas, emissions of biogenic VOCs will increase and potentially result in impacts on regional air quality (O_3 and PM).

Questions:
What compounds are being emitted by Cannabis spp. and how much?
What is emitted released to the atmosphere from indoor and outdoor MCFs?
Are the emissions from MCFs significant on local and regional scales?
Do these emissions impact ozone and particulate matter formation on local and regional scales?

As the regulations on marijuana growing and use change across the US, the impacts of these changes should be evaluated. By performing assessments of the emissions and air quality impacts (or lack of) that result from increases in MCFs in Colorado and Washington states, we can provide a framework of for understanding the air quality impacts of the changing regulations of marijuana growing and usage across the US.

Figure 1: Picture of Marijuana Cultivation Facility

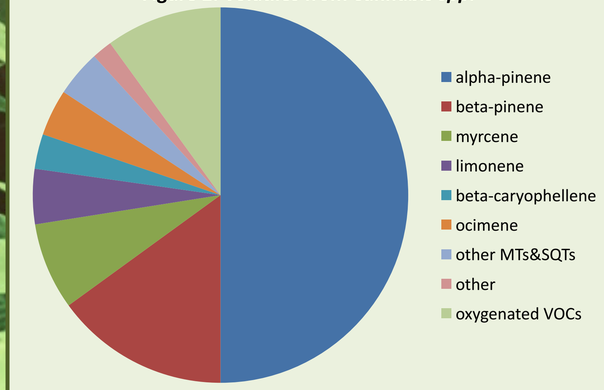
2. VOLATILES FROM *CANNABIS SPP.*

Measurements of emissions from *Cannabis spp*. are limited. Emission factors for *Cannabis spp.* for biogenic VOC emissions modeling are not currently available.

Known volatiles from *Cannabis spp.* include monoterpenes (a-pinene, b-mycrene, b-pinene, and limonene), delta-9-tetrahydrocannabinol (THC, $C_{21}H_{30}O_2$), oxygenated VOCs, and sesquiterpenes (Figure 2; [3-6]).

In cultivation facilities, a-pinene, b-mycrene, b-pinene, and limonene were found to be present in high concentrations (50 to 100 ppb) in the growing rooms. All of the airborne THC levels were below the detection level (0.10 µg/sample) except for one sample (0.70 µg/sample) that was near the detection limit [2].

Figure 2: Volatiles from *Cannabis spp.*



3. QUICK EMISSION ESTIMATES FOR COLORADO

Currently, in Colorado, marijuana cultivation facilities must be in a fully enclosed, locked area. As of 15 June 2014, there are on the order of 1,000 cultivations statewide. The size and location of these are not known at this point, but the number of facilities is changing rapidly (*N. Bryant, State of Colorado, Personal communications, 13 June 2014*).

Jankauskiene and Gruzdeviene [7] report that the dry biomass from two cultivars of *Cannabis sativa* ranged from 162 – 227 g/m^2 (average 195 g/m^2).

Assuming an average MCF size of ½ hectare (5,000 m^2), that equates to 973 metric tons of dry biomass. A total monoterpene emission factor of 5 mg g^{-1} hr^{-1}, assuming that *Cannabis spp.* have total monoterpene emission factors on the same order as other high emitting species (e.g., *Eucalytpus spp.* and *Artemisia spp.* (sage))[8].

Given these initial assumptions, total monoterpene emissions from MCFs are on the order of 43 metric ton yr^{-1}. These estimation methods are valid for cultivation facilities in the outdoors. However, in Colorado, where MCFs must be enclosed, emissions to the atmosphere will also be reduced. There, the amount of biogenic VOCs released into the atmosphere will be a fraction of the total and dependent on the ventilation system at each MCF.

4. IMPLICATIONS

Overall, these first estimates are fairly small compared to other VOC sources in the state of Colorado. However, as the number of facilities increases, the potential to emit significant amounts of biogenic VOCs to the atmosphere becomes a possibility. This could be very important when evaluating impacts on ozone and particulate matter formation.

In the Front Range region of Colorado, much of the Denver metropolitan area including Denver, Boulder, and parts of Weld counties have ozone production that is VOC-limited (*G. Tonnesson, US. EPA Region 08, Personal communications, 10 June 2014*). Therefore, it is possible that increases in VOCs, including emissions from MCFs, could cause increases in ozone concentrations in certain areas.

5. FUTURE WORK

The emissions proposed here are highly uncertain due to the lack of data needed to better constrain the estimation process. We recommend the following for advancing the knowledge with regard to quantifying the atmospheric impacts of the legalization of marijuana in the US:

- Quantify emission factors and biomass densities associated with *Cannabis spp.*
- Determine the number, size and location of MCFs in legalized areas
- Perform sensitivity simulations with chemical transport models to determine if, where, and when emissions from MCFs are important to ozone and particulate formation.

References

[1] N. Aboulaich, M.M. Trigo, H. Bouziane, B. Cabezudo, M. Recio, M. El Kadiri, and M. Ater, *Variations and origin of the atmospheric pollen of Cannabis detected in the province of Tetouan (NW Morocco): 2008-2010*, in *Science of the Total Environment*, 2013, pp. 413-419.
[2] J.W. Martyny, K.A. Serrano, J.W. Schaeffer, and M.V. Van Dyke, *Potential Exposures Associated with Indoor Marijuana Growing Operations*, in *Journal of Occupational and Environmental Hygiene*, 2013, pp. 622-639.
[3] L.V.S. Hood, M.E. Dames, and G.T. Barry, *HEADSPACE VOLATILES OF MARIHUANA*, in *Nature*, 1973, pp. 402-403.
[4] P. Rovellini, L. Folegatti, D. Baglio, S. De Cesarei, P. Fusari, S. Venturini, and A. Cavalieri, *Chemical characterization of oil obtained by the cold pressing of Cannabis sativa L. seeds*, in *Rivista Italiana Delle Sostanze Grasse*, 2013, pp. 139-152.
[5] K.W. Hillig, *A chemotaxonomic analysis of terpenoid variation in Cannabis*, in *Biochemical Systematics and Ecology*, 2004, pp. 875-891.
[6] Z. Mehmedic, D. Slade, H. Denham, S. Chandra, D. Stanford, I.A. Khan, and M.A. ElSohly, *Indoor and outdoor cultivation of cannabis: Is there an effect on the chemical composition of the volatile oil?*, in *Planta Medica*, 2008, pp. 328-328.
[7] Z. Jankauskiene, and E. Gruzdeviene, *Evaluation of Cannabis sativa cultivars in Lithuania*, in *Zemdirbyste-Agriculture*, 2010, pp. 87-96.
[8] C. Wiedinmyer, A. Guenther, P. Harley, N. Hewitt, C. Geron, P. Artaxo, R. Steinbrecher, and R. Rasmussen, *Global Organic Emissions from Vegetation*, in *Emissions of Atmospheric Trace Compounds*, C. Granier, P. Artaxo and C. E. Reeves eds., Kluwer Academic Publishers, Dordrecht, The Netherlands, 2004, pp. 115-170.