Introduction

The Northern Front Range (NFR) region of Colorado has experienced rapid expansion in drilling of shale and tight sands oil and gas reservoirs in recent years due to advances in hydraulic fracturing technology. Currently, there are over 25,000 wells in operation in the Denver-Julesburg Basin. This region has also been designated by the US EPA as federal ozone non-attainment area since 2007 for exceeding the 75 ppbv National Ambient Air Quality Standard.

While historically oil and natural gas (O&NG) exploration has traditionally occurred in rural areas, this dynamic has been changing in recent years, with an increasing number of wells drilled in residential and municipal locations. This has led to growing environmental and public health concerns, including diminished air quality from primary emissions and ozone formation. Here, we present ambient measurements of volatile organic compounds (VOCs) from residential communities across the NFR to investigate the impact of O&NG emissions.

Data

Datasets used in this study were as follows:
- Canister samples (24 hr and 3 hr samples) collected by INSTAR at residences in Erie, Feb–May, 2013 (n = 30)
- Canister samples (3 hr samples) collected by Colorado Dept. of Public Health and Environment (CDPHE) at Platteville and downtown Denver, 2013
- Canister samples (3 day samples) collected at 5 sites in Boulder County, 2014

Study Area

The C2-C5 alkanes, primarily sourced from natural gas, exhibit the greatest ambient mole fractions in Platteville (Fig 2), in the center of the Wattenberg Field, with mean values 5-6 times greater than observed in Erie (on the western periphery of the gas field), 9-15 times greater than in downtown Denver, and highly enhanced over regional backgrounds (Table 1). These compounds account for nearly 90% of total measured ppbv in Platteville, compared with 64% in Denver (Fig 3). Compounds that have primarily urban sources (the alkenes) are highest in Denver, as are some of the aromatic BTX compounds, although BTX are comparable to levels in Platteville (see Fig 5 for further discussion). The 2014 Boulder County Air Quality Study is consistent with these results, confirming highest ambient VOC mole fractions at sites nearest to the gas field operations (Fig 4).

VOC Enhancements

Aromatic compounds, such as benzene (Fig 5) are emitted by both O&NG operations and vehicles. In the NFR, ambient benzene mole fractions are, on average, double in Platteville compared to the Denver metropolitan area. Correlations of benzene with propane (an O&NG tracer) and acetylene (a vehicle/combustion tracer) reveal an R2 of 0.72 with acetylene and 0.29 with propane in Denver, and the reverse in Platteville. This indicates that, not only is the benzene higher in Platteville, but also that the source of benzene in these two areas is distinctly different, with O&NG being the dominant source in Platteville, accounting for ~70%. A recent study by Gilman et al. (2013) determined that O&NG contributed 55% to ambient benzene at the BAO, on the periphery of the Greater Wattenberg.

Comparison with Other Regions

The yearly averages for the C2-C5 alkanes in Platteville are 10-30 times greater than observed in either downtown Los Angeles or near the Houston industrial sector, whereas the aromatic and alkene compounds were comparable in magnitude (Fig 6). These comparisons are remarkable, given the vast difference in populations (Platteville population ~2,600) and the heavy industrial activity in Houston. A useful metric for investigating the influence of urban versus O&NG emissions sources on ambient VOC composition is the benzene/propane ratio. Vehicle tailpipe emissions are more enhanced in propane than are O&NG emissions. Fig 7 shows that this ratio in Erie lies very close to that from raw natural gas emissions, and that contribution from O&NG emissions have significantly increased in Boulder in the last 20 years.

Summary and Conclusions

- Ambient levels of certain VOCs, especially the light alkanes, are highly enhanced in the NFR, with greatest mole fractions observed within the Greater Wattenberg Field.
- Benzene has both urban and O&NG sources, however, correlation analysis reveals that ambient benzene in Platteville and Denver are primarily emitted from distinctly different sources.
- Changes in the benzene/propane ratio in Boulder, relatively removed from (but often downstream of) the gas field operations, reveal an increasing contribution of O&NG emissions in the last 20 years.
- As a whole, O&NG emissions in the NFR represent a large area source of ozone precursors.
- Although CO continues to pass stricter emissions regulations on O&NG operations, the rapid and continuing expansion of wells will likely hinder any real progress in controlling ozone pollution.

References

This work has recently been published in:

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