Remote and Onsite Direct Measurements of Emissions from Oil and Natural Gas Production

Extended Abstract # 551

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INTRODUCTION

Environmentally responsible oil and natural gas production requires accurate knowledge of emissions from long-term production operations, which can include methane (CH_4), volatile organic compounds (VOCs) and hazardous air pollutants (HAPs). Well pad emissions vary based on the geologically-determined composition of the product, production rates, age of the well, production equipment design, and maintenance states of systems and emission control devices. Enclosed combustion devices (ECDs) and vapor recovery units (VRUs) are commonly employed emission control devices. Well pad emissions can be difficult to measure and model due to the large number of potential sources.[1-3] The intermittent nature of flash emissions that occur when pressurized hydrocarbon liquids (oil or condensate) are transferred from a separator into a storage tank at atmospheric pressure adds further complexity. With new questions on ozone impacts and regulations on condensate storage tank emissions in development,[4] speciated emissions and control effectiveness are important emerging topics. This study expands current knowledge of VOC well pad emissions through comparison of several studies spanning a variety of measurement approaches. New data from an EPA onsite study and a series of remote mobile surveys are compared with four previous onsite studies (Table 1).

Table 1. Comparison of field study attributes.

	EPA Onsite	**EPA OTM 33A**	**ERG (2011)**	**Hendler (2006)**	**Gidney (2009)**	**ENVIRON (2010)**
Year of Measurement	2011	2010-2013	2010-2011	2006	2008	2010
Basins	Denver-Julesburg	Barnett, Denver-Julesburg, Pinedale	Barnett	Barnett, Western Gulf	Anadarko, Barnett, Permian	Barnett
Unique Well Pads (N)	23	Barnett: 26 Denver-Julesburg : 36 Pinedale: 61	380	Barnett: 10 Western Gulf: 9	Anadarko: 4 Barnett: 7 Permian:8	3

Average Condensate Production (bbl/day)	34.5	Barnett: 0.15 Denver-Julesburg: 6.7 Pinedale: 10.8	0.01 (6 pads with condensate production)	Barnett: 6.5 Western Gulf: 87.8	Anadarko:72.8 Barnett: 22.3 Permian: 510.3	20.9
Controls at Time of Measurement	ECD[a], VRU[b] condensate tanks	Denver-Julesburg: ECD[a], VRU[b] Barnett: minimal Pinedale: partial	Minimal	None	None	None
Measurement Approach	OGI[c], HVS[d] with GC-FID canister analysis[f]	OTM 33A for CH_4 with GC-FID canister analysis[f]	OGI[c], HVS[d] with TO-15 canister analysis	Seal and measure with GPA Method 2286-95[e]	Seal and measure with GPA Method 2286-95[e]	Seal and measure with GPA Method 2286-95[e]
Measurement Focus	component (tank focus)	Integrated pad	Component (leak focus)	Condensate tank	Condensate tank	Condensate tank
Duration of Measurement	Seconds per point	20 min	Seconds per point	24-hour	24-hour	24-hour

[a] Enclosed Combustor Device; [b]Vapor Recovery Unit; [c]Optical Gas Imaging; [d]High Volume Sampler; [e]Gas Processors Association Method 2286-95[5] [f]Gas Chromatography with Flame Ionization Detection as described in EPA/600-R-98/161[6]

The onsite studies conducted in Texas focused exclusively on well pad condensate tanks using a "seal and measure" approach, routing all potential emissions through a single port monitored by a flow measurement device for a 24-h period[1, 2, 7] and determining the composition of the vented gas using the Gas Processors Association (GPA) Method 2286-95.[5] This somewhat invasive approach guarantees sampling of periodic flash emission events. These onsite studies are compared with the Eastern Research Group (ERG) onsite study in which optical gas imaging (OGI) was used to locate emission points that were then quantified using high volume samplers (HVSs) complemented with canister analyses. The studies are further compared with an EPA Onsite study conducted in the Denver-Julesburg (DJ) Basin and modeled after the ERG study[8] and remote measurements of VOC well pad emissions acquired using a mobile inspection approach, US EPA Other Test Method (OTM) 33A.[9]

METHODS

In the EPA Onsite study, 23 well pads in the DJ Basin were assessed using the methods detailed by ERG.[8] The studies differed in the canister analysis utilized and in the condensate production level and tank emission controls. Only two of the sites in the ERG study utilized controls, while ECDs were present on all of the condensate tanks measured in the EPA Onsite study. From the largest emission point on each well pad, at least one canister was acquired at the exit of the HVS (Bacharach Hi Flow Sampler™, Bacharach, Inc., New Kensington, PA, USA) (n = 33 total). The HVS flow rates were combined with the concentration values from the canisters to calculate emission rates for individual and groups of compounds. Where canisters were not acquired, the default HVS-derived emission rate was utilized. While the ERG study used EPA Method

TO-15[10] for source canister VOC analysis and gas chromatography with a thermal conductivity detector for CH_4 analysis, in the EPA Onsite study the concentrations of total and speciated non-methane volatile organic compounds were determined using Gas Chromatography with Flame Ionization Detection (GC-FID) as described in EPA/600-R-98/161[6] coupled with ASTM 1946/D1945[11] analysis of CH_4, ethane (C_2H_6), and propane (C_3H_8).

The remote monitoring approach EPA OTM 33A[9] was performed to quantify CH_4, VOC, and HAP emissions from well pads during field campaigns in the Colorado DJ Basin, July 2010 and 2011; Texas Barnett Shale, September 2010 and 2011; Wyoming Pinedale, June 2011, July 2012, and June 2013.[9, 12] The canisters collected as part of OTM 33A were analyzed using the same methods as in the EPA Onsite study.[6, 11] To determine individual compound emission estimates, the OTM 33A[9] point source Gaussian (PSG) CH_4 emission assessment from the 20 minute observation is used in conjunction with the canister data in a ratio-based approach.[9] Only canisters with > 100 ppbv CH_4 concentrations above the background value determined by the PSG calculation were used in the analysis to ensure robust plume sampling. No background correction was applied to the non-methane compounds leading to a slight positive bias in results.

As with the onsite measurements, the compound set for the OTM 33A VOC emission assessments includes all C3+ species present in the canister analysis[6, 11] that are present above detection limit. The term VOC used herein does not include CH_4 or C_2H_6 species. Study results were compared using geometric means because VOC emissions were log normally distributed. The mean and 95% CI of the log-transformed data were calculated using a non-parametric bootstrap[13, 14] and then transformed back into the original scale.

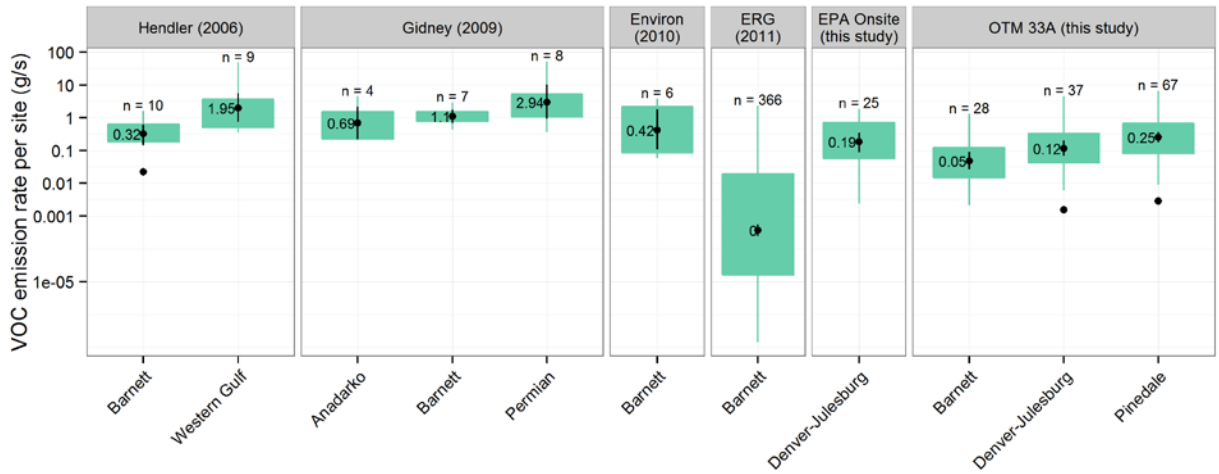
RESULTS

In the EPA Onsite study, 106 emission points were measured with the HVS, and 33 evacuated canisters were acquired and analyzed to establish the composition of the emitted vapor streams. Thief hatches on condensate tanks were one of the most frequently observed leak locations. To determine total well pad VOC emissions for the EPA Onsite study, the HVS measurements without canister values were assigned the mean MW, % VOC concentrations based on the emissions location. Measurements of documented flash emissions in the EPA Onsite study were not included in the site totals because the duration and frequency were unknown. The emissions were then summed by site and compared with measurements from the EPA OTM 33A study as well as previously published studies. A total of 133 canisters out of 201 collected remotely using OTM 33A met data quality criteria and were spatially matched with active well pads.[12]

Differences in production levels, use of controls, basin emission factors, and measurement techniques complicate the comparison of VOC emissions measured in the EPA onsite study with the emissions measured in the other onsite studies. The basin level VOC emission factors used in the 2011 EPA National Emissions Inventory[15] were 3.15, 7.07, 9.76, and 11, 13.7, and 19.6 lbs VOC/bbl of condensate in the Anadarko, Permian, Fort Worth (Barnett), Western Gulf, DJ, and Pinedale basins, respectively. The higher emission factor in the DJ would suggest that the EPA Onsite Study may be higher than the Texas studies, however, the presence of controls and lack of accounting for flash emissions should lead to lower emissions than those observed by Hendler,[1] Gidney,[2] and Environ.[7] The low VOC emissions reported by ERG[8] are in part due to extremely

low condensate production at the sites measured, but also contributing to these low values is the non-optimal canister analysis for VOC determination and short-term nature of the measurement.

Figure 1. Comparison of VOC study results. Boxes represent the 1st and 3rd quartiles of the data, while whiskers extend to the largest measurement that is within 1.5 times the interquartile range (IQR). Geometric means are labeled and are shown in black along with 95 % CIs and were calculated using a non-parametric bootstrap.



SUMMARY

This study provides important information on the emission rates of VOCs from well pads as well as a comparison between different measurement techniques and laboratory analysis protocols. Results from the EPA Onsite Study of VOC emissions from well pads with controls in the DJ indicate that emissions were typically lower than from uncontrolled sites in TX measured in previous studies, but not always significantly. The similarity between the concentrations measured onsite and those measured remotely, suggests that OTM33A can be used effectively as an inspection technique for identifying oil and gas well pads with large fugitive emissions.

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REFERENCES

1. Hendler, A.; Nunn, J.; Lundeen, J.; McKaskle, R. VOC emissions from oil and condensate storage tanks. http://www.bdlaw.com/assets/htmldocuments/ (accessed November 26, 2014).

2. Gidney, B.; Pena, S. Upstream Oil and Gas Storage Tank Project Flash Emissions Models Evaluation Final Report. http://www.bdlaw.com/assets/htmldocuments/ (accessed December 1, 2014).
3. Allen, D. T.; Torres, V. M.; Thomas, J.; Sullivan, D. W.; Harrison, M.; Hendler, A.; Herndon, S. C.; Kolb, C. E.; Fraser, M. P.; Hill, A. D. Measurements of methane emissions at natural gas production sites in the United States. *Proceedings of the National Academy of Sciences* 2013, 110, 17768-17773.
4. CDPHE. 5 CCR 1001-9: Control of Ozone via Ozone Precursors and Control of Hydrocarbons via Oil and Gas Emissions (Emissions of Volatile Organic Compounds and Nitrogen Oxides). http://www.colorado.gov/ (accessed November 26, 2014).
5. GPA. *GPA Standard 2286-95 Tentative Method of Extendend Analysis for Natural Gas and Similar Gaseous Mixtures by Temperature Programmed Gas Chromatography*. Gas Processors Association: Tulsa, Oklahoma 1999; Vol. Adopted as a Tentative Standard 1986, Reprinted 1989, 1991, 1995, Revised 1995, Reprinted 1997, 1998, 1999, .
6. EPA. Technical Assistance Document for Sampling and Analysis of Ozone Precursors. http://www.epa.gov/ttnamti1/files/ambient/pams/newtad.pdf (accessed November 26, 2014).
7. ENVIRON. Upstream Oil and Gas Tank Emission Measurements. https://www.tceq.texas.gov/assets/public/implementation/air/am/contracts/reports/ei/5820784004FY1025-20100830-environ-Oil_Gas_Tank_Emission_Measurements.pdf (accessed November 26, 2014).
8. ERG. City of Fort Worth Natural Gas Air Quality Study Final Report. http://fortworthtexas.gov/uploadedFiles/Gas_Wells/AirQualityStudy_final.pdf (accessed December 1, 2014).
9. EPA. DRAFT " Other Test Method" OTM 33A (Ver 1.2) Geospatial Measurement of Air Pollution-Remote Emissions Quantification-Direct Assessment (GMAP-REQ-DA). http://www.epa.gov/ttn/emc/prelim.html (accessed Decemeber 1, 2014).
10. EPA. EPA/625/R-96/10b: Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air, Second Edition, Compendium Method TO-15, Determination Of Volatile Organic Compounds (VOCs) In Air Collected In Specially-Prepared Canisters And Analyzed By Gas Chromatography/Mass Spectrometry (GC/MS). http://www.epa.gov/ttnamti1/files/ambient/airtox/to-15r.pdf (accessed November 26, 2014).
11. ASTM. ASTM D1945-03 Standard test method for analysis of natural gas by gas chromatography ASTM International: West Conshohocken, PA, 2010. www.astm.org.
12. Brantley, H. L.; Thoma, E. D.; Squier, W. C.; Guven, B. B.; Lyon, D. Assessement of Methane Emissions from Oil and Gas Production Pads Using Mobile Measurements. *ES&T* 2014, Just Accepted.
13. Wickham, H. *ggplot2: elegant graphics for data analysis*. Springer New York: 2009.
14. Harrell Jr, F. E.; Dupont, C. *Hmisc R package version 3.14-1*. 2007.
15. EPA. National Emissions Inventory Oil and Gas Emissions Estimation Tool. ftp://ftp.epa.gov/EmisInventory/2011nei/doc/EPA_Oil_and_Gas_Production_Emission_Estimation_Tool_2011_NEI_V1_4_20130919.zip (accessed December 1, 2014).