Oil and Natural Gas Development Impacts to Air Quality: NETL's Air Sampling Initiatives

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INTRODUCTION

The Energy Policy Act of 2005, Title IX, Subtitle J, Section 999 provided funding for the National Energy Technology Laboratory to research the environmental impacts of oil and natural gas exploration and production activities. Developing environment friendly technologies and/or management strategies ensures that oil and gas development proceeds at a rate that protects the environment while maintaining an adequate domestic supply. The NETL research effort includes (1) conducting targeted on-site measurements of emissions from oil and gas production activities using a trailer-based autonomous air monitoring laboratory, and (2) using the collected data as input or to verify both atmospheric chemistry and transport models and life cycle assessments of natural gas development greenhouse gas emissions. NETL's mobile air monitoring laboratory houses instrumentation to measure ambient concentrations of several pollutants as well as meteorological parameters. In addition, a wireless monitoring network developed by West Virginia University researchers through NETL's Regional University Alliance (RUA) measures pollutant concentrations around a selected source using several strategically placed nodes, or monitors, to provide estimates of pollutant dispersion and transport. The mobile air monitoring laboratory and the wireless monitoring network were deployed to the Allegheny National Forest (ANF) in northwestern Pennsylvania for a year-long campaign (July 2010 – June 2011). Historically a productive area for oil and gas wells, the 513,000 acre forest has seen the number of wells increase significantly from 8,000 in 2005 to currently over 12,000, and increasing development of the deeper Marcellus shale formation is expected[1]. The federal government owns surface rights in the ANF but 93% of the underlying mineral rights are privately owned. Three monitoring locations were selected within the ANF the Kane Experimental Forest (KEF) area in Elk County, which is downwind of the Sackett oilfield; the Bradford Ranger Station (BRS) in McKean County, which is downwind of a large area of historic productivity; and the U.S. Forest Service Hearts Content (HC) campground in Warren County, which is in an area relatively unimpacted by oil and gas development and therefore yielded background pollutant concentrations in the ANF.

NETL is currently using the mobile air monitoring laboratory to measure pollutant concentrations at Marcellus Shale wells to estimate the emissions from well completions. This approach of directly estimating impacts from oil and gas development sources will improve

modeling assessments, such as NETL's life cycle assessment (http://www.netl.doe.gov/energy-analyses/pubs/NG-GHG-LCI.pdf), on which permitting and regulatory decisions are based.

EXPERIMENTAL METHODS

Mobile Air Monitoring Laboratory

NETL operates a mobile air monitoring laboratory that is equipped with monitors to measure pollutants listed in Table 1. The laboratory was designed to be autonomous with personnel conducting visits on a weekly basis to perform instrument maintenance, calibrations and troubleshooting. A satellite link provided communications such that the laboratory computers could be accessed remotely for downloading of data and control of some of the instruments. The station required an external source of electric power at each monitoring location. A main sampling inlet on the roof of the laboratory led to a blower and manifold from which instruments received a flow of ambient air. Two instruments, the TEOM and the Sunset Labs OC/EC analyzer, required their own air inlets. The blower, operating at 30 scfm, kept the flow of ambient air constant at the inlet and provided adequate flow for instrument exhaust to the exterior of the trailer.

Table 1. Instrumentation in NETL's mobile air monitoring laboratory.

Instrument	Parameters Measured	Measurement Technique	Time Resolution
Picarro G2201i $\delta^{13}C$ CH_4, CO_2	CH_4, CO_2, and Isotopic Carbon in CH_4 and CO_2	Cavity Ring-down Spectroscopy	~1s
Picarro G1103 Ammonia Analyzer	NH_3	Cavity Ring-down Spectroscopy	~1s
Perkin Elmer Ozone Precursor Analyzer System	VOCs (52 compounds on the EPA PAMS standard list)	GC-FID with thermal desorption	1h
Teledyne-API NO_x Analyzer	NO, NO_2	Chemiluminescence	1min
Teledyne-API Ozone Analyzer	O_3	UV Absorption	1min
Teledyne-API SO_2 Analyzer	SO_2	Fluroescence	1min
Thermo Scientific TEOM 1405-DF	PM_{10}, $PM_{2.5}$	Microbalance	1h
Sunset Laboratory Field Organic and Elemental Carbon Analyzer	OC, EC	Quartz oven with NDIR	2h
Davis Instruments Vantage Pro2 Plus	Air Temperature, Relative Humidity, Atmospheric Pressure, Wind Speed and Direction, Precipitation, Solar Intensity	Various meteorological sensors	1min

Wireless Air Monitoring System (WAMS)

The WAMS uses a wireless signal to transfer data from a selected monitor to a base station. The number of monitors, or nodes, is unlimited. The nodes can be strategically placed around a source, and the range of communication from a node to a base station can be as far as 25km. A daisy-chain configuration of nodes can increase the distance, provided each node is within range of another. The selection of a monitor is experiment-specific. When the WAMS was tested in the ANF, each module comprised of a TSI (Shoreview, MN) model 8530 Dusttrack aerosol monitor, which is a light scattering, direct-reading dust monitor; radio transceiver; a 12-volt battery-powered monitoring device and a battery all sheltered in a bright orange case. A two-foot by five-foot solar panel kept the battery fully charged. A small, notebook-sized computer with cell phone modem housed in NETL's mobile air monitoring laboratory served as the base station, to receive the data from the monitoring modules. The wireless system sent data from the module locations to a website server accessed remotely. The WAMS was deployed at the KEF site in the ANF during four weeks in August 2010. Two sets of samplers were located near the mobile air monitoring laboratory, one in a lightly wooded area and the other in a more heavily wooded area. The system was designed to be inexpensive and easy to use in a wide variety of situations.

RESULTS AND DISCUSSION

ANF Monitoring Campaign

Criteria pollutants measured at the three monitoring locations within the ANF varied little between sites as shown in Table 2. Ozone has an 8-hour standard of 75 ppb and a 1-hour standard of 120 ppb[2]. Hourly ozone maximums at all three sites were not higher than 60 ppb. Nitrogen dioxide has an annual average standard of 53 ppb and a 1-hour primary standard of 100 ppb[2]. NO_x concentrations at each of the three monitoring sites were generally very low with short-term peaks that indicated interception of NO_x plumes from individual sources. PM_{10} and $PM_{2.5}$ concentrations are only available for the KEF site, as the TEOM units were malfunctioning at the HC and BRS sites. PM_{10} has a 24-hour standard of 150 $\mu g/m^3$ and $PM_{2.5}$ has an annual average standard of 15 $\mu g/m^3$ as well as a 24-hour standard of 35 $\mu g/m^3$.[2]

Table 2. Criteria air pollutants measured during the ANF monitoring campaign.

Pollutant	Range of Monthly Averages at KEF Site	Average at HC Site	Average at BRS Site
Ozone	35-46 ppb	42 ppb	42 ppb
NO_x	0.9-1.5 ppb	1.7 ppb	1.5 ppb
PM_{10}	7-23 $\mu g/m^3$	(Not measured)	(Not measured)
$PM_{2.5}$	5-18 $\mu g/m^3$	(Not measured)	(Not measured)

Other studies of air quality impacts from oil and gas development have reported concentrations for specific VOCs. The Texas Commission on Environmental Quality conducted air monitoring projects connected to the development of the Barnett Shale formation, with the reported high concentrations of benzene causing great concern.[4] Conversely, the Southwestern Pennsylvania Marcellus Shale Short-Term Ambient Air Sampling study conducted by the PA Department of Environmental Protection concluded that concentrations of benzene and other VOCs emitted

from natural gas production activities did not indicate a potential for major air-related health issues.[5] Average concentrations of several of the measured VOCs measured at the three sites in the ANF, with maximum measured concentration and percent of samples detected at concentrations above the detection limit, are presented in Table 3. Results for VOCs that were measured but detected in less than 10% of the samples are not shown.

Table 3. Concentrations of VOCs measured during the ANF monitoring campaign.

VOC	KEF Site			BRS Site			HC Site		
	Avg[a]	Max[b]	%ADL[c]	Avg	Max	%ADL	Avg	Max	%ADL
Ethane	10.3	70	100	10.3	117	65	9.2	42	100
Ethylene	0.72	2.4	74	0.22	3.2	23	0.41	2.6	66
Propane	6.6	34	100	7.7	90.4	65	4.9	28	100
Isobutane	3.3	13	97	1.8	18.6	60	0.96	7.3	59
n-Butane	0.23	3.1	17	3.5	35.3	64	2.3	12.4	94
Acetylene	1.7	7.6	83	---	---	<10	0.17	4.1	13
Cis2butene	0.20	2.9	16	---	---	<10	---	---	<10
Isopentane	3.5	12	99	2.6	13.6	65	1.4	5.1	86
n-Pentane	1.5	5.6	91	1.5	11.2	60	1.1	5.2	77
Isoprene	0.40	5.8	12	0.09	3.7	4	0.30	30.4	4
Hexane	0.12	2.4	15	0.44	4.0	41	---	---	<10
Benzene	0.40	2.5	41	0.13	1.6	18	0.27	4.0	29
Toluene	1.6	4.4	99	1.4	12.1	86	1.25	7.0	99
Ethylbenzene	0.35	5.0	39	0.16	2.5	27	1.4	19.4	42
m,p-xylene	0.75	5.7	63	0.40	8.4	39	1.4	16.9	41
Styrene	2.1	10	96	0.82	4.9	53	0.12	3.1	10
m-ethyltoluene	0.21	3.9	24	0.58	3.5	56	0.35	3.9	32
o-xylene	---	---	<10	---	---	<10	0.69	9.0	36
1,2,3-trimethylbenzene	0.43	3.3	40	1.19	4.4	63	0.79	6.5	53

[a]Avg (SD): Average concentration in ppb.
[b]Max: Maximum concentration in ppb.
[c]%ADL: % of samples above the detection limit.

Although most average VOC concentrations are higher at the KEF and BRS sites, there are three compounds for which higher average concentrations were actually observed at the HC, or background, site: ethylbenzene, m,p-xylene, and o-xylene. The behavior of isoprene was unusual, as it was typically not detected; however, there were six occasions of isolated, large peaks lasting 4-7 hours indicating interception of a plume. Two of the incidents were at the KEF site, one at the BRS site, and three were at the HC site. Measured concentrations were as high as 30 ppb.

Approximately 403,000 data points from the Dusttrack monitors that were part of the WAMS operated from August 13-16, 2010. Measurements were typically less than 20 $\mu g/m^3$. Despite the somewhat remote nature of the sampling site, the concentration of dust exceeded the range capacity of the receiver several times during the sampling period (>120 $\mu g/m^3$).

SUMMARY

Concentrations of gaseous and particulate pollutants measured at three sites within the ANF from July 2010 through June 2011 are reported here. Concentrations of ozone, NO_x, PM_{10}, and $PM_{2.5}$ were well below the National Ambient Air Quality Standards. Several VOCs were consistently

detected but concentrations were typically less than 10 ppb. An initial comparison of criteria pollutant data from the three sites shows similar concentrations, but differences in the behavior of several VOCs were observed. Concentrations of VOCs were not always lowest at the background site. This brief summary of the air monitoring campaign in the ANF does not include analysis of some of the measured pollutants or statistical evaluation of pollutant concentrations at each site. Future work will include a complete reporting of all pollutant behaviors, including statistical analyses to determine statistically significant differences between sites, as well as examination of meteorological data to determine probable source areas.

NETL will be using the information obtained from future ambient air monitoring campaigns at several sites in southwestern Pennsylvania and northern West Virginia to evaluate contribution of pollutants to local air quality during Marcellus Shale well completions. Results will be compared to estimates used in NETL's life cycle assessment of greenhouse gas emissions from unconventional natural gas production.[6]

REFERENCES

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KEYWORDS

Oil and gas, shale, air sampling initiatives