Long-Term, Open-Path Emissions Monitoring at Oil and Gas Exploration and Production Sites

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ABSTRACT

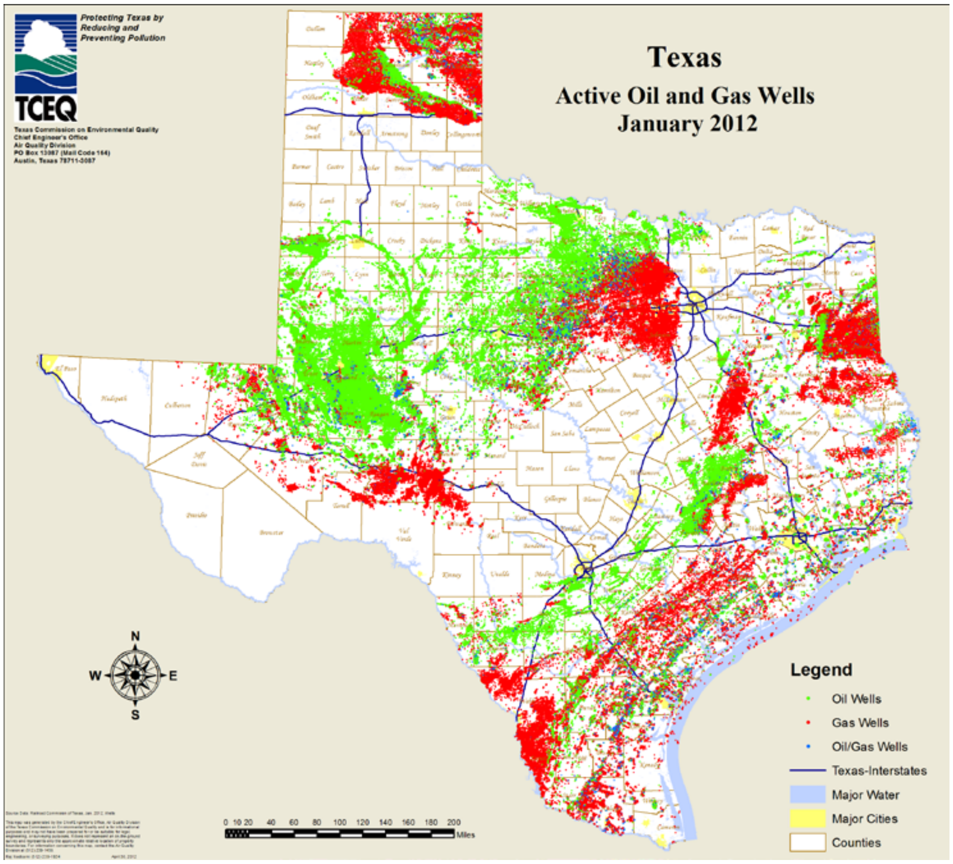
Oil and gas exploration and production ("E&P") operations are highly distributed, both geographically and with respect to responsibility. Globally, literally thousands of entities are engaged in E&P activities. Methane and air toxic emissions from E&P operations are often ignored or poorly understood. Recent developments in the United States are requiring better accounting and reporting of greenhouse gas ("GHG") emissions from domestic oil and gas E&P operations; for example, the Mandatory GHG Reporting requirements found in 40 CFR 98, Subpart W. There is also increasing interest in the exposure of fenceline communities to air toxics emitted from E&P facilities. However, the available factor-based methodologies provide only a rough approximation of actual GHG and air toxics emissions from fugitive emission sources associated with E&P activities. Short-term studies around E&P facilities provide only a "snap-shot" of actual emissions that may or may not be representative of long-term emissions. Integration of open-path monitoring technologies into long-term sampling programs at E&P facilities will result in more robust data for use in developing better, long-term emission factors and in evaluating emission variability over extended timeframes. The data will also provide operators with valuable information that can be integrated into their loss prevention and compliance programs.

INTRODUCTION

The global infrastructure for finding, producing, transporting, refining and distributing oil and gas is massive and pervasive. Oil and natural gas is produced in some quantity in nearly every corner of the world. The Energy Information Administration reports that there were over 350,000 active oil wells and nearly 450,000 active natural gas wells in the United States in 2009. In Texas alone there were over a quarter of a million active oil and natural gas wells in 2009.[1] Figure 1 shows just how widespread – and how many – oil and gas production wells are in the State of Texas.[2]

A key requirement for developing a robust, effective air quality management plan is having a good understanding of emission sources and magnitudes. It is broadly believed, however that emissions from E&P operations have been historically underreported or unreported. A recent study led by scientists at the US National Oceanic and Atmospheric Administration ("NOAA") and published in 2012 indicates that emissions of hydrocarbons, especially light alkanes, from E&P operations in the Denver-Julesburg Basin ("DJB") of Eastern Colorado may be very large relative to previous estimates.[3] This study concluded that methane emissions from E&P operations in the DJB were between 2.3 and 7.7% of natural gas production. While yet another 'red flag' for the oil and gas industry, this (and other) studies do not provide any real insight into how to more accurately estimate emissions from this sector. At the most basic level, these studies simply confirm what is already known: that E&P operations are significant sources of light alkanes and that existing emission inventories are inadequate.

Figure 1. Active oil and gas wells in Texas
(Source: Texas Commission on Environmental Quality)



CURRENT APPROACHES FOR ESTIMATING HYDROCARBON EMISSIONS FROM E&P OPERATIONS

Emission inventories for E&P operations have often been developed using a bottom-up methodology that relies upon emission factors developed from limited testing and equipment counts. An example is the Texas Commission on Environmental Quality ("TCEQ") estimating volatile organic compounds ("VOCs") emissions from condensate storage tanks using a 33.3 lb/barrel emission factor derived from a report prepared for the Texas Environmental Research Consortium ("TERC").[4] Needless to say, the potential for error with this method is significant.

The oil & gas industry has a number of effective tools available for estimating emissions of hydrocarbons from point sources associated with major processing units. These include:

- GRI-GLYCalc® for estimation of emissions from glycol dehydration units;
- API E&P Tank® model for flashing emissions from storage tanks;
- Process simulators such as HYSIM® and HYSIS® that are used to estimate emissions from various production and processing unit operations; and
- Direct measurement.

The Mandatory Greenhouse Gas Reporting Rule for Petroleum and Natural Gas Systems (40 CFR 98, Subpart W) identifies these and other tools for use in estimating and reporting GHG emissions. A limitation of any sophisticated emission estimation approach is, however, the availability and use of accurate inputs. And, of course, the owner/operator has to make the effort necessary to collect the required data and to apply the tools correctly. The GHG Reporting Rule also relies upon use of emission factors for a number of important potential emission sources including venting of pneumatic devices and equipment leaks. The accuracy of any estimate made using generic emission factors is always of questionable accuracy. The requirements of the GHG Reporting Rule do not apply to VOCs.

How accurate will the initial inventories of GHGs from E&P operations under the Mandatory Reporting Rule be? Our collective experience with large, stationary sources of hydrocarbons, such as petroleum refineries and petrochemical manufacturing plants, is not encouraging. In 2000, one of the findings of the Texas Air Quality Study ("TexAQS") was that emissions of non-methane hydrocarbons in the Houston, Texas, area were underestimated and underreported by a factor of 3-15.[5] This is after decades of experience preparing emission inventories.

USE OF OPEN-PATH MONITORING TO IMPROVE EMISSION INVENTORIES

Combining Short- and Long-Term Measurement Techniques

In December 2011, the USEPA published guidance for measuring and monitoring fugitive emissions using optical remote sensing.[6] In the introduction to Chapter 3, Measurements Applicable to Emissions Flux, this document adopts the basic approach advocated in this paper: use of three types of data to accurately quantify and characterize annual emissions from a specific fugitive source. These three types of data are:

1. *Intensive, short-term studies to measure mass flux*. These studies would be conducted using technologies such as Differential Absorption Light Detection and Ranging ("DIAL"), Solar Occultation Flux ("SOF") and Vertical Radial Plume Mapping ("VRPM").
2. *Plume characterization / speciation* using tools such as open-path Fourier Transform Infrared ("OP-FTIR").
3. *Long-term to permanent monitoring* at the facility fenceline or at the boundary of the processing area of interest.

Short-term flux studies and plume characterization should be the precursor, or pilot-stage, of long-term monitoring at the boundary of an area or fugitive emissions site. Long-term monitoring should be used to determine trends of area sources emissions and to provide an indication of seasonal or industrial-cycle emissions variability. When coupled with the findings from intensive, short-term studies, relatively simple, single-beam downwind open-path monitoring systems can be used to accurately estimate emissions over long periods of time. This approach can be used to overcome one of the primary objections from industry to the use of open-path monitoring technologies like SOF and DIAL to estimate emissions: that the findings of short-term studies are not necessarily representative of longer-term emissions.

EPA's efforts at quantifying emission from E&P operations are currently focused on the Geospatial Measurement of Air Pollution – Remote Emission Quantification ("GMAP REQ") stage: a series of multiple, short-term flux measurement campaigns.[7] These are "snap-shot" studies focused on finding methane leaks and quantifying VOCs emissions relative to estimated methane emissions. By measuring VOCs only within detected methane plumes and assuming a strong correlation between methane and VOC emissions, these studies may result in an over- or under-estimation of VOC emissions at sites where there is not a good correlation with methane emissions. Furthermore, quantifying methane fluxes only at sites where methane leaks were detected may lead to misrepresentation of typical methne emissions from these sites.

While recognizing the value of long-term studies, it is the authors' understanding that EPA currently has no near-term plans for combining the GMAP REQ approach with long-term emission studies.

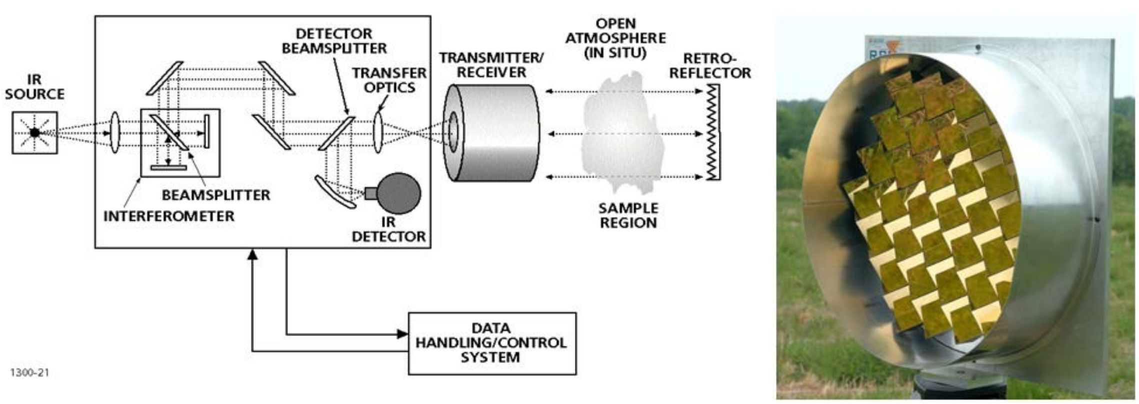
The Power of OP-FTIR

There are several open-path technologies that can be deployed in simple, single-beam configurations including Tunable Diode Lasers ("TDLAS"), Differential Optical Absorption Spectroscopy ("DOAS"), and OP-FTIR. In the author's opinion, OP-FTIR is the most powerful and flexible technology for use in long-term monitoring programs at E&P sites as it can monitor almost all compounds of interest simultaneously.

Active monostatic OP-FTIR sensors, as shown in Figure 2, are capable of detecting and measuring a large number of atmospheric species and contaminants simultaneously including:

- Alkanes such as methane, and butane/octanes as a total alkane mixture (OP-FTIR is not capable of speciating individual alkanes in very low concentrations);
- Aromatics including benzene, toluene, ethylbenzene and xylenes (BTEX);
- Highly-reactive VOCs (HRVOCs) such as ethylene and propylene; and
- Other air toxics such as formaldehyde and styrene.

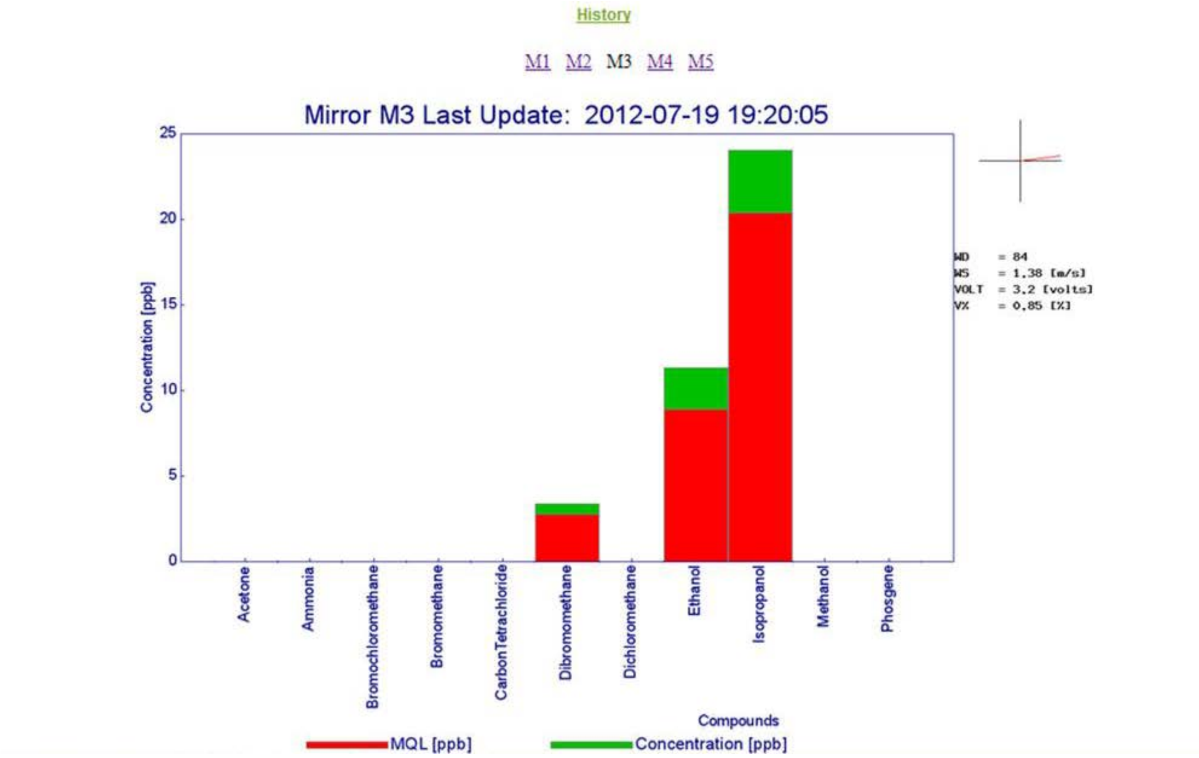
Figure 2. Illustration of an active monostatic OP-FTIR sensor



Further, recent advancements in OP-FTIR data processing allow for reliable, real-time analysis and presentation of multiple pollutant concentrations.

Figure 3 is an example of pollutant concentration data from a scanning OP-FTIR system owned and operate by Atmosfir Optics Ltd. (www.atmosfir.net). This example is from an organic pesticide manufacturing site. The OP-FTIR is collecting data over five variable-beam path lengths along the fenceline – M1-M5 in a 1-D Radial Plume Mapping ("RPM") configuration as described within U.S. EPA Other Test Method 10 ("OTM 10").[8] In this example, spectral data collected is being continuously monitored for the presence and concentration of nine organic and two inorganic pollutants of concern. The screenshot Figure 3 shows the detection of three pollutants of concern on beam path M3 at the last minute of data collection: dibromomethane, ethanol, and isopropanol. The end use may also view at time series (history) of any predefined pollutant at any of the beam paths and within a predetermined time interval (e.g last 24 hours)

Figure 3. Screenshot of real time OP-FTIR data from a pesticide manufacturing facility (Source: Atmosfir Optics Ltd.)



Incorporating synchronized wind data may direct site personnel to the area of major leaks. Real-time data access if via a password-protected internet site.

Use of OP-FTIR at E&P Facilities

OP-FTIR has been deployed successfully at E&P facilities. USEPA used OTM 10 to estimate emissions from produced water ponds at two test sites in Colorado.[9] Figure 4 depicts a VRPM (as described in OTM 10) 4-corners configuration around a produce water pond.

The findings from the produced water pond study demonstrate that good correlation between methane and VOC emissions should not be assumed. Figure 5 shows downwind concentrations of various pollutants, including total alkanes and methane, over the course of approximately 1 hour 45 minutes. The wind during the course of this measurement series changed directions so that, at some times, only emissions from the produced water pond were being measured while, at other times, emissions from other locations within the entire production facility were being measured. As shown, during the first few minutes, there is good correlation between total alkane and methane concentrations. However, as the time series progresses, the correlation between emissions of methane and the other pollutants being measured lessens. If only methane was measured and a static relationship between methane and VOCs assumed, in this case emissions of VOCs would have been significantly underestimated.

Figure 4. OTM 10 measurement configuration at a produced water pond in Colorado (Source: USEPA)

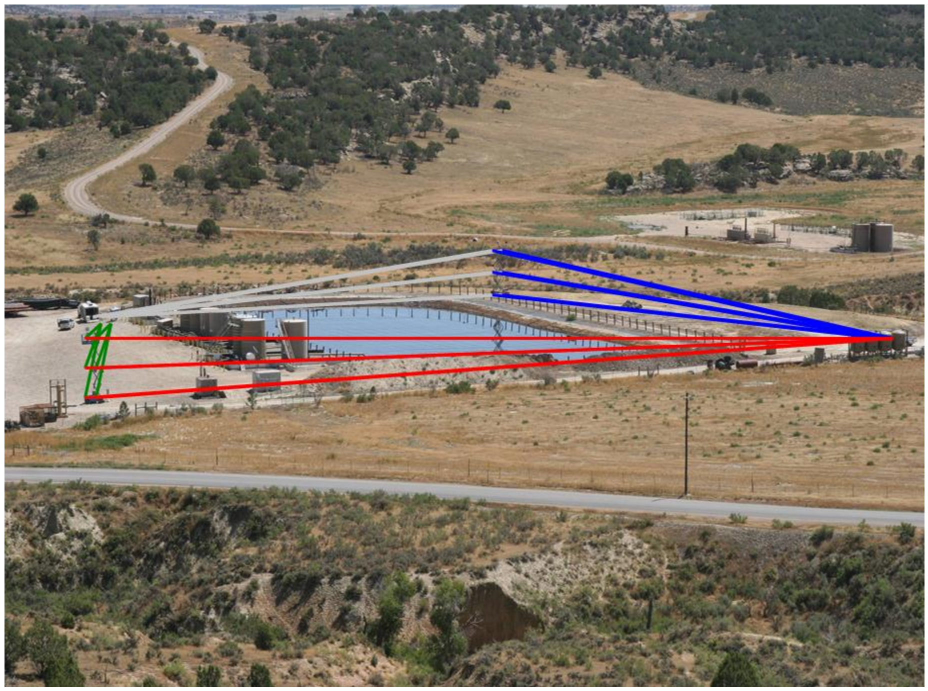
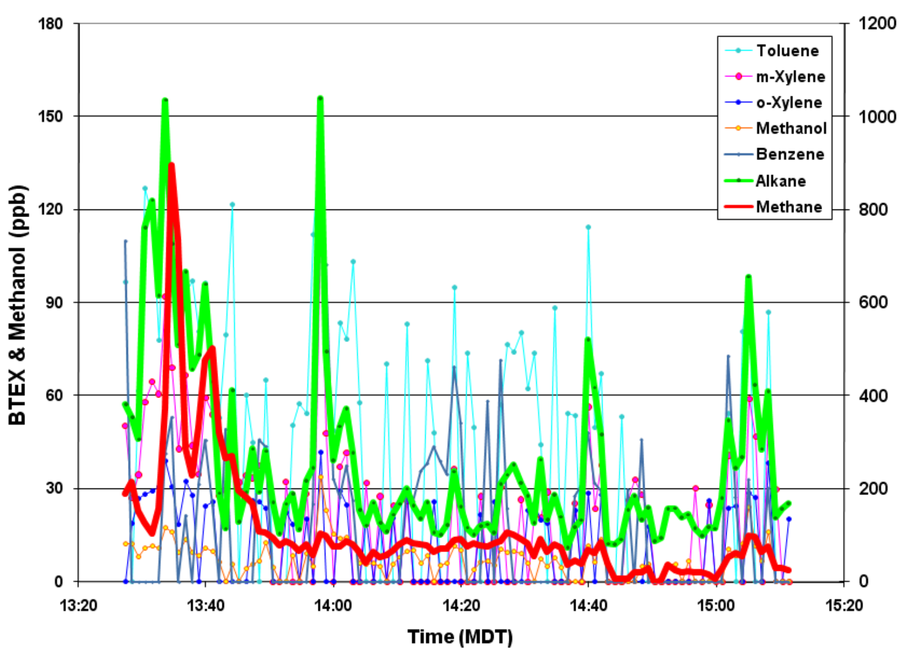


Figure 5. Downwind concentrations of various hydrocarbons at a produced water pond in Colorado

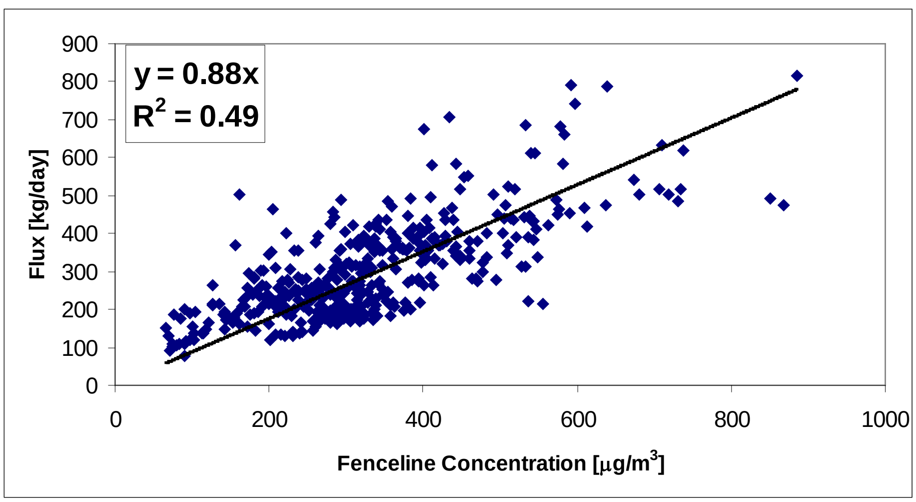


Correlating Concentration with Mass Flux

As previously discussed, intensive short-term measurement campaigns can be used to provide an estimate of the short-term emissions and concentrations of selected target compounds or surrogates at complex area sources. Findings from short-term measurement programs, when combined with long-term fenceline monitoring, can be used to provide good estimates of long-term emissions.

Figure 6 shows the relationship between the measured downwind fenceline concentration of elemental mercury ("Hg") from a single-beam open-path UV-DOAS instrument and the Hg mass flux at a chlor-alkali plant as measured using the VRPM method as described in OTM 10.[10] For this installation, the correlation between concentration and mass flux is sufficient to allow for use of a single beam OP instrument to make reasonably accurate annual emission estimates. Of course, this requires conducting short-term measurements campaigns (using DIAL, SOF, VRPM, etc.) while taking single-beam measurements, and constructing the site specific correlation between concentration and mass flux.

Figure 6. Relationship between Hg mass flux as measured using VRPM and fenceline concentration as measured using a single beam UV-DOAS at a chlor-alkali plant



USE BEYOND EMISSION INVENTORY IMPROVEMENTS

Beyond the value of better air quality management programs resulting from improved emission inventories, there are a number of other benefits that may be realized by E&P companies through the use of open-path long-term emission monitoring programs. These benefits may include:

- *Affirmative defense*. E&P operations are under significant community and political pressure to reduce emissions. More aggressive monitoring approaches will provide some measure of proof that the industry is being proactive in quantifying and managing their air emissions. The data collected can also be used to demonstrate that the facility (or facilities) is in compliance with various mass emission-based regulatory programs such as Federal New Source Review and Title V Operating Permits.

- *Improved financial performance through enhanced loss prevention / hydrocarbon recovery programs.* Monitoring findings can be used to direct and focus routine and turnaround maintenance activities. Monitoring findings can also be used to identify equipment with higher failure potential, as evidenced by leakage, and repairing the equipment in a timely manner; thus increasing reliability and reducing downtime.
- *Improved community relations*. Enhanced monitoring that results in reduced emissions and community exposure to air pollutants should result in improved relations with the fenceline and downwind communities.
- *Reduced exposure to litigation*. By reducing emissions and resultant air quality impacts in the surrounding communities, exposure to litigation and the resultant costs (legal, settlement, reputational, etc.) should be reduced.

The old adage is true, you can't manage what you don't measure.

CONCLUSIONS

When coupled with the findings from intensive, short-term emission studies (conducting using technologies such as DIAL, SOF or VRPM), relatively simple, single-beam open-path monitoring systems can be used to accurately estimate emissions over long periods of time. This approach can be used to overcome one of the primary objections that industry has had to use of open-path monitoring: that short-term emissions may not be representative of long-term emission. In addition to the benefits derived from more accurate emission inventories (e.g. better air quality management plans), operating companies may derive additional benefits from long-term monitoring including improved regulatory compliance, enhanced loss prevention / hydrocarbon recovery programs, improved community relations, and reduced exposure to litigation.

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KEY WORDS

Atmosfir Optics Ltd.
Exploration and production
Fenceline monitoring
Fourier Transform Infrared
Oil and gas
Open-path monitoring
OP-FTIR
Other Test Method 10
OTM 10
Vertical Radial Plume Mapping
VRPM