Optical Remote Sensing of Fugitive Emissions
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## Optical Remote Sensing

<table>
<thead>
<tr>
<th>What it does</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detect presence of pollutants, but provide little quantitative information</td>
<td>Current-generation passive IR cameras</td>
</tr>
<tr>
<td>Presence and concentration, but not mass flux</td>
<td>1-D, uncorrelated FTIR monitoring</td>
</tr>
<tr>
<td>Presence, concentrations and mass fluxes</td>
<td>Differential Absorption LIDAR, Solar Occultation Flux and Vertical Radial Plume Mapping, when integrated with meteorological data</td>
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</tbody>
</table>
Differential Absorption LIDAR ("DIAL")

- Backscatter DIAL was developed by Shell and BP in the 1980s.
  - BP sold their system to Spectrasyne in 1992.
  - Shell sold their system to the UK National Physical Laboratory in 2002.

- Spectrasyne has completed more than 150 surveys, most in Northern Europe. NPL has conducted a handful since refurbishing the Shell system.

- Surveys conducted in North America:
  - Canadian refiner (2005)
  - Canadian oil sands production facility (2005)
  - Texas City refinery and storage terminal (2007)
  - Houston refinery (2007)
  - Midwest landfill (2008)
  - Canadian coke oven battery (2008)
  - Houston refinery (scheduled for 2009)
  - Texas flares (schedule TBD)

- Use now being specified in consent orders and information collection requests.
Spectrasyne testing of a refinery in Göteborg, Sweden, between 1988 and 1999 showed measured emissions consistently exceeded calculated emissions, even after six years of surveys.

Findings could indicate:
- The DIAL survey results do not accurately reflect actual emissions.
- Short-term emissions, as measured by DIAL, are not indicative of long-term emission rates.
- The refinery was not using emission factors properly.
- The emission factors represent an oversimplification of refinery operations and, as a result, may not be able to consistently estimate emissions accurately.
DIAL: Texas City Study

- Study was conducted during July 2007 by the U.K. National Physical Laboratory (NPL) under the direction of the TCEQ at industrial sites in Texas City.
- DIAL was used to measure total hydrocarbon emissions from:
  - Crude and product storage tanks
  - Delayed Coker
  - Flares
- DOAS was used in conjunction with DIAL to measure benzene emissions.
### DIAL:
Texas City Study

<table>
<thead>
<tr>
<th>Source Type</th>
<th>VOC Emissions (lbs/hr)&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Benzene Emissions (lbs/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk Terminal Storage Tanks</td>
<td>1 – 33</td>
<td>NA</td>
</tr>
<tr>
<td>Distillate Product Storage Tanks</td>
<td>&lt;1 – 32</td>
<td>NA</td>
</tr>
<tr>
<td>Crude Oil Tanks</td>
<td>&lt;1 – 54</td>
<td>NA</td>
</tr>
<tr>
<td>Gasoline Storage Tanks</td>
<td>&lt;1 – 18</td>
<td>NA</td>
</tr>
<tr>
<td>Wastewater Treatment Plant</td>
<td>5 – 42</td>
<td>NA</td>
</tr>
<tr>
<td>Delayed Coker</td>
<td>4 – 32&lt;sup&gt;2&lt;/sup&gt;</td>
<td>0.0 – 2.1</td>
</tr>
<tr>
<td>Heated Oil Tanks</td>
<td>1 – 15</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Emergency Release Flare</strong></td>
<td>147 – 263&lt;sup&gt;2&lt;/sup&gt;</td>
<td>NA</td>
</tr>
</tbody>
</table>

<sup>1</sup> VOC = C<sub>3+</sub> Hydrocarbons  
<sup>2</sup> Average emissions during the course of the survey
Implication of DIAL Study: Concern About Flares

- Texas City study indicated that the effectiveness of one, new emergency flare in controlling routine emissions may have been significantly less than the assumed 98%.
  - Is it steam rates?
  - Is it a problem of the flare just being too big for the routine flows?
  - Is it both?
  - Is it something else?

- Flare investigations have been initiated by the EPA and the TCEQ.

- EPA is focusing on compliance with 40 CFR 60.18 design criteria.

- TCEQ’s approach is more ambitious and holistic: figure flares out!
Limitations in Using DIAL

- Limited in-field validation measurements show 8-15% uncertainties. [In validation studies, DIAL measurements were lower than actual emissions due to incomplete plume capture.]
- Wind speed and direction are the largest known source of error in the backscatter DIAL technique.
- Plume penetration can be limited by high concentrations of particulate, steam plumes, weather conditions (such as rain and snow).
- Both commercial providers of DIAL are located in the UK.
- Logistics and cost are major challenges in getting DIAL surveys conducted in the US – expect to pay $250,000 - $750,000 for a DIAL survey.
- No EPA methods or written guidance. For surveys, EPA is requiring and approving case-specific Quality Assurance Project Plans.
- Measures emissions over a short time period. Estimation of long-term emissions using DIAL survey results is subject to same questions as use of any short-term measurement (e.g. stack testing using EPA reference methods).
Solar Occultation Flux ("SOF")

- Commercial provider is FluxSense of Sweden.
- SOF has been used to conduct annual emission surveys at several Swedish refineries and chemical plants since 2001.
- Participated in TexAQS II during the summer of 2006.
- DIAL and subsequent SOF studies conducted at refinery in Göteborg, Sweden show good correlation.

Mont Belvieu area became a focus area for additional investigations.

Ethylene Survey – September 19, 2006

Source: FluxSense AB
Limitations in Using SOF

- Uncertainty in results is typically 20-50%.
- To reduce uncertainties associated with wind-field disturbances near structures and sources, ideally, measurements are made 0.5-2 km downwind of the source.
- Wind speed and direction are the largest known source of error in the SOF technique.
- Technique works best when mobile platform is maintaining a constant speed of between 30-35 mph.
- Single commercial provider is located in Sweden, presenting logistics challenges.
- No EPA methods or written guidance.
Vertical Radial Plume Mapping

“Poor Man’s DIAL”

- Technique was developed at the University of Washington and they own the intellectual property rights. Licensing agreement is required to use VRPM.

- EPA Other Technical Method 10 (“OTM-10) provides guidance on methodology. **Only mass measurement ORS technique with a written EPA method.**

- Has been used with FTIR, DOAS and TDLS instruments.

- Has been used to measure emissions from low-to-the-ground sources such as:
  - Landfills
  - Confined animal feeding operations
  - Superfund & Brownfield sites
  - Chlor-alkali plant
  - Phosphate processing plant
  - Refueling stations
  - Petroleum refinery process units
  - Chemical plants
  - Barges
  - Oil & gas production facilities

- Can be installed to collect data over long periods of time.
VRPM Plume Reconstructions
Chlor-Alkali Plant

Bistatic UV-DOAS Sources (3)

Location of LUMEX Mercury Analyzer

Water Tower
53 m

Bistatic UV-DOAS Receivers

Cell Room

09/21/06 1602 Draft Data

Flux: 45.6  Leakage: 0.0 [g/hr]  Wind Dir/Speed: 33.9 [degrees] / 5.9 [m/s]

ng m⁻³
0 649.5
0 433.0
0 216.5
0
Limitations in Using VRPM

- Validation studies show uncertainties in measurements of ±10%.
- Needs a reflective surface high enough to allow most of the plume to pass below the highest beam of the array.
- VRPM may underestimate actual emissions due to incomplete plume capture.
- Like SOF and DIAL, wind speed and direction are the largest known source of error in the VRPM technique.
- Need people who know what they are doing to conduct spectral analysis and VRPM calculations.

Source: IMACC
Optical Remote Sensing: 
Findings are Changing the Approach to Air Quality Management

- **Upstream oil & gas:**
  - Tank batteries maybe a large source of unreported / underreported hydrocarbon emissions.

- **Flares:**
  - Texas City study indicated that the effectiveness of one, new emergency 40 CFR 60.18-conformant flare was much less than the AQM assumption that flares are 98% effective. There are over 600 flares in the Houston area alone.

- **Refineries & chemical plants:**
  - ORS surveys indicate that overall emissions from tanks, wastewater treatment facilities, process fugitives, and delayed cokers are often much greater than what is estimated using API emission factors.

- **EPA is now specifying use of ORS in consent decrees and Section 114 ICRs.**

- **EPA seems interested in using ORS techniques to improve emission factors.**
Optical Remote Sensing: Significant Implications of Findings

- ORS findings have been used in enforcement proceedings:
  - Passive IR camera images used to support claim that facilities are not meeting “general duty” obligations to maintain equipment and emission controls in proper working condition.

- Many federal and state regulatory programs have emission threshold triggers. Flawed emission estimation techniques could result in inaccurate determinations of applicability.

- The entire New Source Review permitting program assumes that approved emission estimation techniques are accurate.

- Neighboring communities will not be pleased if they learn that sources have been underestimating emissions and communities have been exposed to higher-than-estimated concentrations of pollutants.
  - Tort liability
  - Environmental justice claims
Conclusions & Recommendations:

- ORS technologies have demonstrated their value as tools to help identify and quantify sources of emissions. However, application in the U.S. has not been widespread.

- ORS technologies, especially DIAL, need to be generally more available and at a lower cost.

- More ORS surveys need to be conducted and the information from those surveys needs to be made available for:
  1. Critical review by regulatory agencies and the regulated community.
  2. Use in improving emission estimation techniques.

- Regulatory agency use of facility-initiated ORS survey findings as credible evidence in enforcement proceedings will be exceptionally counterproductive. They need to be thinking of ways to provide incentives and eliminate barriers.

- We need standards and EPA-approved guidance for use of ORS to address questions about the validity of the technologies and survey techniques.

- We need a master plan for using ORS survey findings to improve emission factors.