Field Evaluations of Using Vertical Radial Plume Mapping for Emission Rate Estimations in Petro Chemical Industries

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Outline

• Introduction
  – VRPM

• Methods
  – Field studies (industrial complex)
  – Algorithms for flux estimation

• Results

• Discussions and Conclusion
Introduction
Introduction

• Air pollutants vs. health effects

• Source Strength
  – Emission rate / Flux
  – Air quality control
  – Environmental Impact Assessment
  – Dispersion models

VOCs
Introduction

- **Point sources**
  - e.g. stacks, vents, …
  - in-stack monitors (concentration, flow rate)

- **Fugitive emissions**
  - e.g. leaking valves, fittings, …
  - Emission factors
    - U.S. EPA’s Method AP-42 Compilation of Air Pollutant Emission Factors
    - Large uncertainty / not plant specific / no temporal resolution
Introduction

• Fugitive emissions
    • Optical Remote Sensing for Emission Characterization from Non-point Sources
  – OP-FTIR
Introduction

• Vertical Radial Plume Mapping (VRPM)

Figure 2. Example of a VRPM Configuration Setup
Objective

• Evaluate the feasibility of implementing VRPM in complicated petro-chemical industries
  – Two field campaigns
  – Tracer gases were released to verify the accuracy of the estimation results
Methods
Methods

<table>
<thead>
<tr>
<th>ARRANGEMENT</th>
<th>Campaign 1</th>
<th>Campaign 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>10\textsuperscript{th} to 13\textsuperscript{th} Feb.</td>
<td>22\textsuperscript{nd} to 27\textsuperscript{th} May.</td>
</tr>
<tr>
<td>Target process</td>
<td>ABS process</td>
<td>EVA process</td>
</tr>
<tr>
<td>Size of target process</td>
<td>L:55m, W:26m, H:8m</td>
<td>L:108m, W:58m, H:15m</td>
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<tr>
<td>Heights of retroreflectors</td>
<td>1.5m, 5m, 12m</td>
<td>8.5m, 16.4m, 24.4m</td>
</tr>
<tr>
<td>Lengths of downwind beam paths</td>
<td>~116 m</td>
<td>~184 m</td>
</tr>
<tr>
<td>Tracer gas flow rate</td>
<td>0.056 g/s</td>
<td>0.092 g/s</td>
</tr>
<tr>
<td>Heights of meteorological stations</td>
<td>2 m, 12.5 m</td>
<td>8.5 m, 25 m</td>
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</tbody>
</table>
Path integrated concentration (PIC) in ppb-m

SBFM reconstruction

Plume distribution in the vertical plane in ppb

Wind speed / wind direction

emission rates
SBFM
(Smooth Basis Function Minimization)

Measured PIC

Predicted PIC

$\text{SSE} = \sum_i \left( \text{PIC}_{\text{observed},i} - \text{PIC}_{\text{predicted},i} \right)^2$

Minimize

Estimate Parameters

$\text{PIC}_{\text{predicted},i}(p_{jk}) = \sum_k \int_0^L G_k(r, \theta, p_{jk}) dr$
Results
Results

• Reasons for underestimation
  – Low wind speed (< 1 m/s)
  – 2\textsuperscript{nd} campaign
    • Original n=208
    • n=28: highest concentration at the ground beam path and the lowest concentration at the upper beam path
    • n=3: wind direction was within 60 degrees from perpendicular (to the vertical plane)
(before)

(b) 2009/05/20

upwind  downwind

(c) 2009/05/21

upwind  downwind

(during)

(a) 2009/05/22

upwind  downwind

(b) 2009/05/23

upwind  downwind
Conclusions

• VOCs: higher than the values from AP-42
  – Tracer gas: underestimation
  – The actual flux of VOCs could be even higher than what we estimate here
  – ‘Conservative’ estimations

• Lesson learned
  – Proper wind condition is critical
    • Longer monitoring period (e.g. > 1 wk) might be necessary for the VRPM approach
Thanks for your attention.