

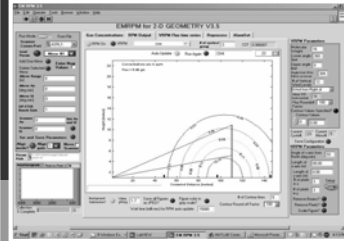


# Innovative Air Monitoring at Landfills Using Optical Remote Sensing with Radial Plume Mapping

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## Outline

- Landfill gas emissions
  - Health and environmental concerns
  - Trends impacting emissions
- Optical Remote Sensing (ORS) technology
- The Radial Plume Mapping (RPM) method
- Demonstration of software with real-time analysis
- Summary/Acknowledgements
- Publication List



## Landfill Gas (LFG) Health & Environmental Concerns

- LFG contains 40-60% methane, 60-40% CO<sub>2</sub>, and trace constituents of volatile organic compounds (VOC), hazardous air pollutants (HAPs), and persistent bioaccumulative toxics
- Landfills identified in EPA's Urban Air Toxic Strategy and are to be evaluated for residual risk
  - More than 30 HAPs detected in LFG
  - Organo-mercury and other metals also found in landfill gas
  - Combustion by-products can also be of concern in nonattainment regions
- Concern for explosive potential of the gas and odor nuisance
- Largest source of methane in the U.S. which includes emissions from older, closed landfills; construction & demolition debris landfills; industrial landfills; and brownfield sites

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Is a designated pollutant under the Clean Air Act because of the explosive potential of the gas, emissions of volatile organic compound (VOC), hazardous air pollutants (HAPs), persistent bioaccumulative toxics (PBTs), and greenhouse gases (methane, CO<sub>2</sub>).

Landfill methane most amenable to cost-effective control through methane utilization



## Trends Impacting Emissions

- Adoption of wet/bioreactor operations where
  - Alternative covers or porous materials are used to promote infiltration which results in larger loss of fugitive emissions
  - There is a delay in LFG capture/control from onset of liquid additions
- More widespread use of landfills for recreational use or development
  - Desire is to put controls in and walk away. However, effective LFG control requires maintenance of cap and well field over time.
- Increase in metals content in landfill from addition of leachate, sewage sludge, treated wood, and industrial waste; uncertainty in potential increase in air toxics.

## Surface Cracks



## Picture of Aerobic Landfill\*



\*Aerobic operation at this site has been discontinued.

## Scanning IMACC OP-FTIR



# Scanning Boreal TDL System







## Radial Plume Mapping Method

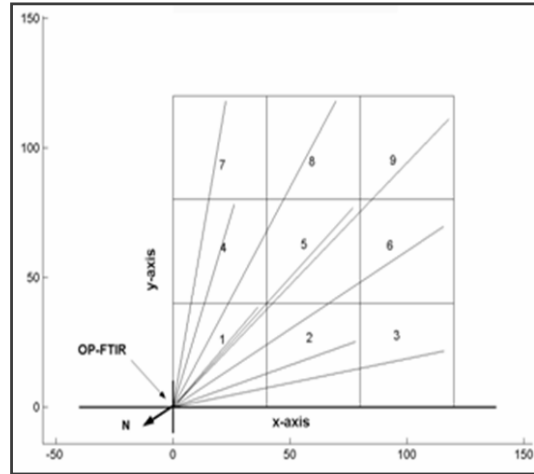
- In 1999, researchers from the U.S. EPA Air Pollution Prevention and Control Division of the National Risk Management Research Laboratory (NRMRL/APPCD) and ARCADIS began work investigating and characterizing emissions from area sources using the RPM method, which was developed at the University of Washington.
- The RPM method uses a simple configuration of a non-overlapping radial beam geometry to map the concentration distributions in a plane.



## Horizontal Radial Plume Mapping (HRPM) Method

- Requires only a single instrument that is scanned horizontally in a radial pattern to several retro-reflecting mirrors located along different path-lengths.
- Using optimization algorithms, the path-integrated concentration data is converted into spatially-distributed concentration maps showing the location of emissions “hot spots”.

## Example HRPM Configuration

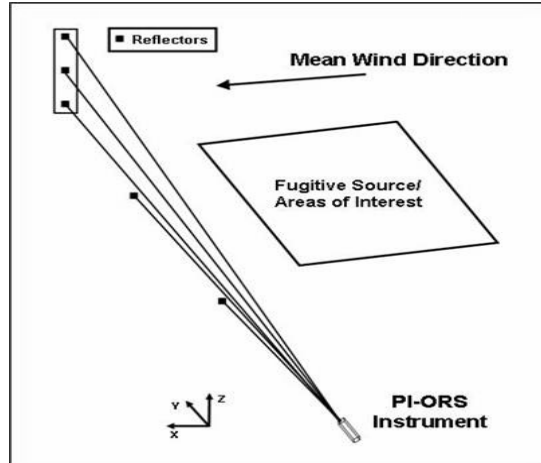


## Vertical Radial Plume Mapping (VRPM)

- The VRPM configuration consists of several optical beam paths deployed downwind from an area emission source.
- Incorporating wind information, the flux through the plane can be directly calculated, leading to a direct, measurement-based estimation of an emission rate for the upwind area source.



## Example VRPM Configuration



## Picture of Active Landfill



# Orange County Demonstration



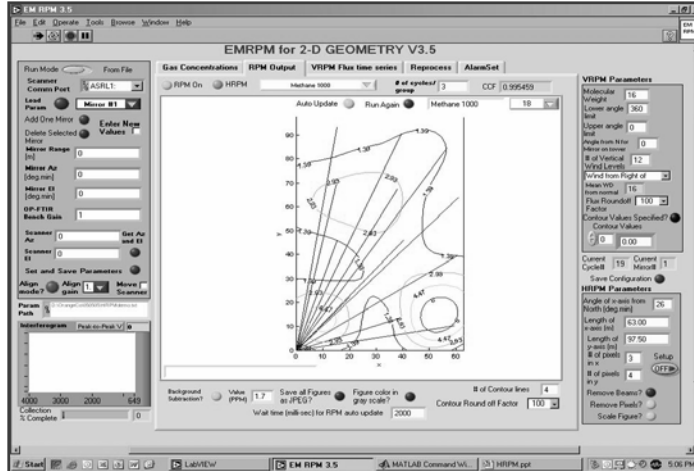


## Real-Time Radial Plume Mapping Software

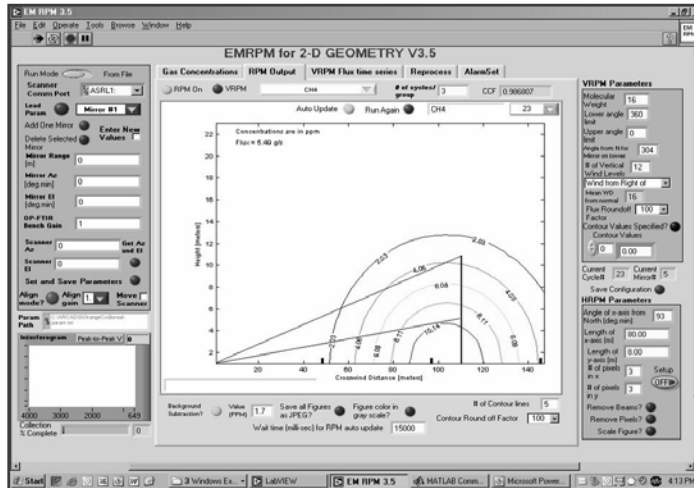
- ARCADIS RPM software was used during the demonstration
- The software is used to control data acquisition from the ORS instrumentation and wind monitors, and control scanner movement
- The software displays the measured concentrations, and horizontal and vertical plume maps in near real-time



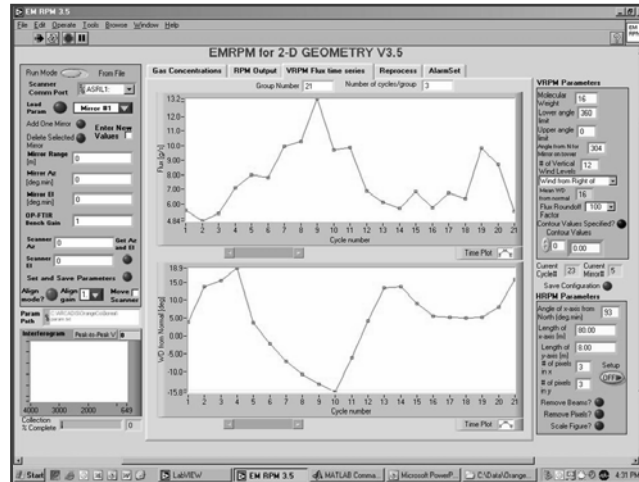
# HRPM Output from Real-Time Software



# VRPM Output from Real-Time Software



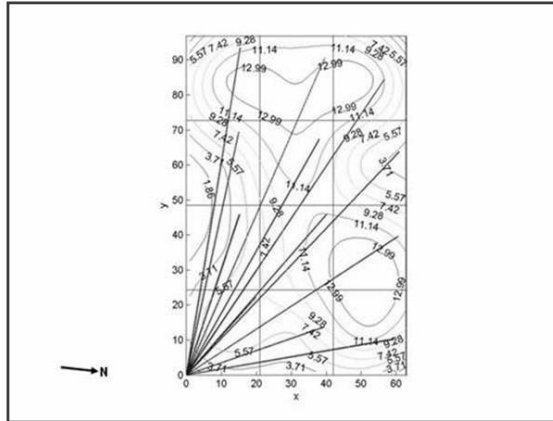
# Time Series of Emissions from Real-Time Software



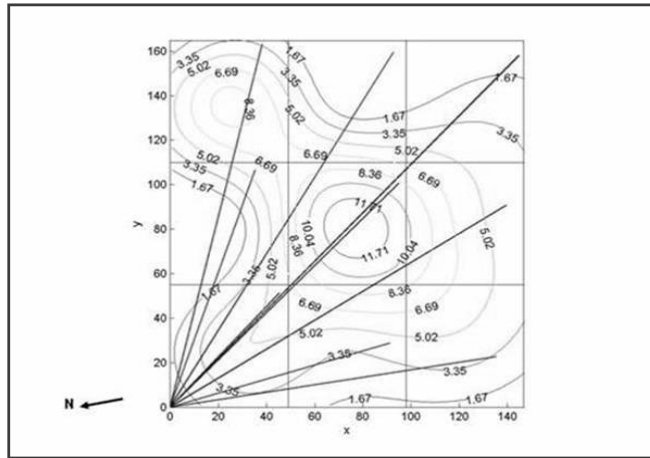
# Orange County Demonstration



## Methane Surface Concentration Contour Map from an HRPM Survey Conducted in the Active Landfill (concentrations in ppm)

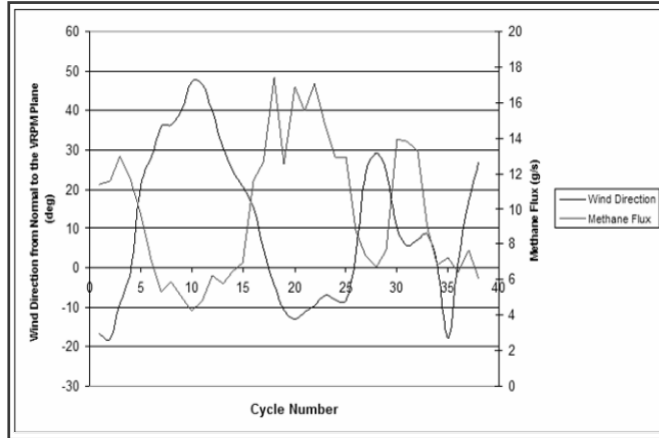


## Methane Surface Concentration Contour Map from an HRPM Survey Conducted in the Closed Landfill (concentrations in ppm)

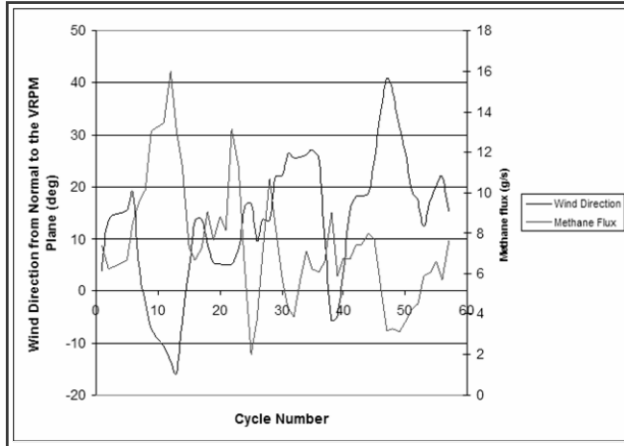




# Time Series of Wind Direction and Methane Flux Values (in g/s) from a VRPM Survey of the Active Landfill Using the IMACC OP-FTIR



## Time Series of Wind Direction and Methane Flux Values (in g/s) from a VRPM Survey of the Active Landfill Using the Boreal TDL Instrument





# Summary

- The RPM method using ORS instrumentation is a viable method for characterizing fugitive emissions from large area sources such as landfills
- The method uses direct measurements to characterize emissions fluxes downwind of sources
- The OP-FTIR and OP-TDL methane measurements produced comparable results downwind of the same source area



## Acknowledgements

- This study was sponsored by the U.S. EPA's Office of Superfund Remediation and Technology Innovation, Technology Integration and Information Branch under its Monitoring and Measurement for the 21st Century (21M2) initiative.
- For further information on ORS technology–  
<http://www.clu-in.org/programs/21m2/openpath/>
- For further information on EPA protocol for conducting ORS measurements–  
<http://www.epa.gov/ttn/emc/new.html>

# USEPA OTM-10

FINAL ORS Protocol  
June 14, 2006

## Optical Remote Sensing for Emission Characterization from Non-point Sources

### 1.0 Scope and Application

1.1 *Introduction:* This protocol provides the user with methodologies for characterizing gaseous emissions from non-point pollutant sources. These methodologies use an open-path, Path-Integrated Optical Remote Sensing (PI-ORS) system in multiple beam configurations to directly identify "hot spots" and measure emission fluxes. Basic knowledge of a PI-ORS system and the ability to obtain quality path-integrated concentration (PIC) data is assumed. The user must be capable of using commercial software to utilize the procedures and algorithms explained in this protocol. The methodologies in this protocol have been well developed, evaluated, demonstrated, validated, and peer-reviewed.<sup>1-12</sup>

NOTE 1 — Any mention of a "PI-ORS system" in this protocol refers to the open-path PI-ORS instrument itself, as well as any associated components used, such as mirrors, scanners, and software.

This protocol does not discuss specific applications (e.g., hog farms, landfills), but provides general guidelines or procedures that can be applied. Detailed protocols for specific applications may be added at a future date.



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Test methods can be divided into several categories:

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- [Category B: Source Category Approved Alternative Methods](#)
- [Category C: Other Methods](#)
- [Category D: Historic Conditional Methods](#)

#### Inte

A fundamental component of the EMC web site is to provide information regard test methods into four different categories. The categories are based on the legal s

<http://www.epa.gov/ttn/emc/tmethods.html>

<http://www.epa.gov/ttn/emc/prelim/otm10.pdf>



## EPA Guidance

**EPA-600/R-05/123a**

[http://www.epa.gov/ORD/  
NRMRL/pubs/600r05123/  
600r05123.pdf](http://www.epa.gov/ORD/NRMRL/pubs/600r05123/600r05123.pdf)

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EPA-600/R-05/123a  
September 2005

## GUIDANCE FOR EVALUATING LANDFILL GAS EMISSIONS FROM CLOSED OR ABANDONED FACILITIES





## EPA Landfill Gas Publications Providing ORS-RPM Data

Measurements of Fugitive Emissions at Region I Landfill (EPA-600/R-04-001, Jan 2004). Available at: <http://www.epa.gov/appcdwww/apb/EPA-600-R-04-001.pdf>.

Evaluation of Former Landfill Site in Fort Collins, Colorado Using Ground-Based Optical Remote Sensing Technology (EPA-600/R-05/-42, April 2005). Available at: <http://www.epa.gov/ORD/NRMRL/pubs/600r05042/600r05042.htm>

Evaluation of Former Landfill Site in Colorado Springs, Colorado Using Ground-Based Optical Remote Sensing Technology (EPA-600/R-05/-41, April 2005). Available at: <http://www.epa.gov/ORD/NRMRL/pubs/600r05041/600r05041.htm>

Evaluation of Fugitive Emissions Using Ground-Based Optical Remote Sensing Technology (In Administrative review; Expect publication in May 07) – Report provides

- Overview of ORS technology,
- Findings from plume capture study; and
- Summary of ORS-RPM landfill data.



## **EPA Landfill Gas Publications Providing Data on Wet/Bioreactor Landfills**

Measurement of Fugitive Emissions at a Bioreactor Landfill (EPA 600/R-05-Aug 2005). Available at:

<http://www.epa.gov/ORD/NRMRL/pubs/600r05096/600r05096.pdf>.

First-Order Kinetic Gas Generation Model Parameters for Wet Landfills (EPA/600/R-05/072, June 2005). Available

at: <http://www.epa.gov/ORD/NRMRL/pubs/600r05072/600r05072.htm>

Measurement of Fugitive Emissions at a Landfill Practicing Leachate Recirculation and Air Injection (EPA/600-R-05/088, June 2005). Available

at: <http://www.epa.gov/ORD/NRMRL/pubs/600r05088/600r05088.htm>



## Guidance for Evaluating Landfill Gas Emissions from “Old” Landfills

Guidance for Evaluating Landfill Gas Emissions from Closed or Abandoned Facilities (EPA-600/R-05/123a). Available at:  
<http://www.epa.gov/ORD/NRMRL/pubs/600r05123/600r05123.pdf>.

Quality Assurance Project Plan for Guidance for Evaluating Landfill Gas Emissions from Closed or Abandoned Facilities (EPA-600/R-05/123b). Available at:  
<http://www.epa.gov/ORD/NRMRL/pubs/600r05123/600r05123b.pdf>.

Case Study Demonstrating U.S. EPA Guidance for Evaluating Landfill Gas Emissions from Closed or Abandoned Facilities at the Bush Valley Superfund Landfill, Abingdon, Maryland (EPA/600/R-05/143). Available at:  
<http://www.epa.gov/nrmrl/pubs/600r05143/600r05143.pdf>.

Case Study Demonstrating the U.S. EPA Guidance for Evaluating Landfill Gas Emissions from the Rose Hill Regional Landfill; Kingstown, Rhode Island (EPA/600/R-05/141). Available at:  
<http://www.epa.gov/ord/NRMRL/pubs/600r05141/600r05141.htm>

Case Study Demonstrating the U.S. EPA Guidance for Evaluating Landfill Gas Emissions from the Somersworth Sanitary Landfill; Somersworth, NH (EPA/600/R-05/142) Available at: <http://www.epa.gov/ORD/NRMRL/pubs/600r05142/600r05142.htm>



## Other EPA Landfill Gas Publications

Landfill Gas Emission Model (LandGEM) - Software and Manual (EPA-600/R-05/047, May 2005).

Available at:

<http://www.epa.gov/ORD/NRMRL/pubs/600r05047/600r05047.htm>

Field Test Measurements at Five MSW Landfills with Combustion Control Technology for Landfill Gas Emissions (Cleared peer & QA review; in Administrative review; Expect to be published by May 07)





## Select Journal Publications

- Hashmonay, R.A., and M.G. Yost, Innovative approach for estimating fugitive gaseous fluxes using computed tomography and remote optical sensing techniques, *J. Air Waste Manage. Assoc.*, 49, 966-972, 1999.
- Hashmonay, R.A., D.F. Natschke, K. Wagoner, D.B. Harris, E.L. Thompson, and M.G. Yost, Field evaluation of a method for estimating gaseous fluxes from area sources using open-path Fourier transform infrared, *Environ. Sci. Technol.*, 35, 2309-2313, 2001.
- Hashmonay, R.A., K. Wagoner, D.F. Natschke, D.B. Harris, and E.L. Thompson, Radial computed tomography of air contaminants using optical remote sensing, presented June 23-27, 2002 at the AWMA 95th Annual Conference and Exhibition, Baltimore, MD.
- Hashmonay, R.A., M.G. Yost, and C. Wu, Computed tomography of air pollutants using radial scanning path-integrated optical remote sensing, *Atmos. Environ.*, 33, 267-274, 1999.
- Hashmonay, R.A., M.G. Yost, D.B. Harris, and E.L. Thompson, Simulation study for gaseous fluxes from an area source using computed tomography and optical remote sensing, presented at SPIE Conference on Environmental Monitoring and Remediation Technologies, Boston, MA, Nov., 1998, in SPIE Vol. 3534, 405-410.
- Modrak, M. T.; Hashmonay, R. A.; Kagann, R. *Measurement of Fugitive Emissions at a Region I Landfill*; EPA-600/R-04-001; U.S. Environmental Protection Agency, Research and Development, Work Assignment No. 4-003, January 2004.
- Modrak, M. T.; Hashmonay, R. A.; Varma R.; Kagann, R. *Evaluation of Fugitive Emissions at a Brownfield Landfill in Ft. Collins, Colorado Using Ground-Based Optical Remote Sensing Technology*; EPA-600/R-05/042; U.S. Environmental Protection Agency, Research and Development, Work Assignment No. 0-025, March 2005.
- Modrak, M. T.; Hashmonay, R. A.; Varma R.; Kagann, R. *Evaluation of Fugitive Emissions at a Brownfield Landfill in Colorado Springs, Colorado Using Ground-Based Optical Remote Sensing Technology*; EPA-600/R-05/041; U.S. Environmental Protection Agency, Research and Development, Work Assignment No. 0-025, March 2005.
- Open Path Tunable Diode Laser Absorption Spectroscopy for Acquisition of Fugitive Emission Flux Data; Thoma, E. D., R. C. Shores, E. L. Thompson, D. B. Harris, S. A. Thorneloe, R. M., Varma, R. A. Hashmonay, M. T. Modrak, D. F. Natschke, and H. A. Gamble. *Journal of Air and Waste Management Association*. (55), 658-668 (2005).
- Wu, C., M.G. Yost, R.A. Hashmonay, and D.Y. Park, Experimental evaluation of a radial beam geometry for mapping air pollutants using optical remote sensing and computed tomography, *Atmos. Environ.*, 33, 4709-4716, 1999.



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