U.S. EPA's Perspective on Landfill Gas Modeling - Presentation for World Bank Workshop on Landfill Gas

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April 19, 2007

EPA United States Environmental Protection Agency

Outline

- Health and environmental concerns
  - Evolution of U.S. guidance and regulations for landfill gas emissions
  - Trends impacting future emissions
- EPA's approach to quantifying landfill gas emissions
  - Modeling
    - Regulatory applications
    - Life-cycle analysis
  - Measurements
- Ongoing research to reduce uncertainties associated with quantifying landfill gas emissions
- Selected publications
- Conclusions

Health & Environmental Concerns

- Once waste is deposited in a landfill, emissions are generated for decades.
- Most immediate concern is for the explosive potential of the gas and potential for landfill fires.
- Emissions of concern include
  - greenhouse gas emissions,
  - volatile organic compounds,
  - hazardous air pollutants,
  - persistent bioaccumulative toxics,
  - hydrogen sulfide, and
  - H_2.

Landfill Gas Capture and Control

- Area source emissions – with temporal and spatial variability.
- Effective gas capture requires maintenance and monitoring over time of the cover material, gas well field and header pipes, and combustion technology.
- When landfill gas is collected and controlled, combustion by-products are formed.
- Even the best landfill gas capture and control systems do not collect all of the gas that is generated.

Evolution of U.S. Guidance and Regulations for MSW Landfills

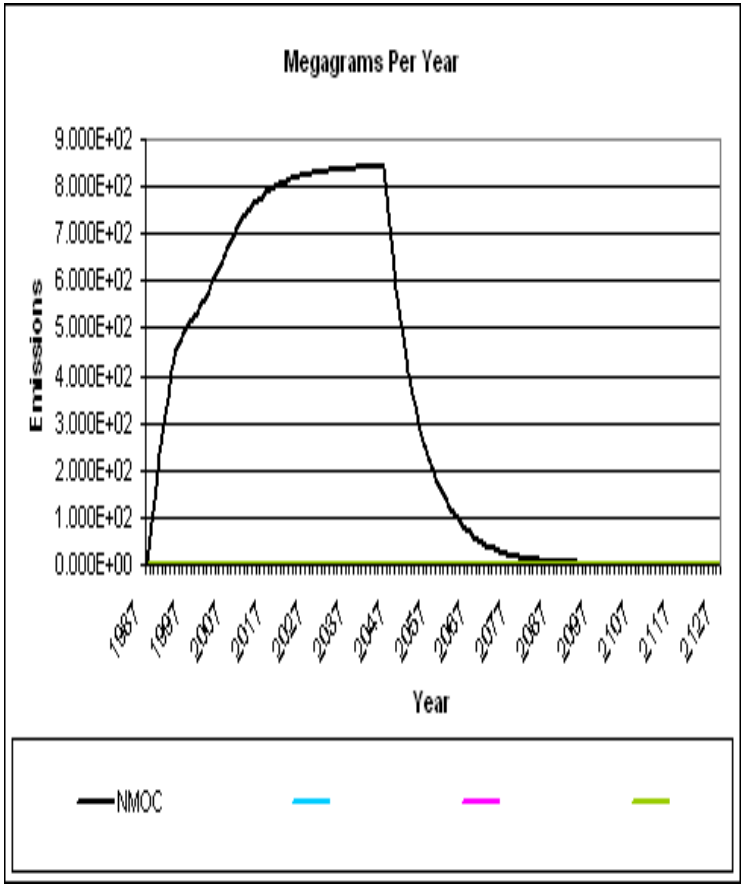
- 1984 – First effort to model landfill gas emissions as part of RCRA Subtitle D regulation for MSW landfills
- 1986 – Decision to regulate under Clean Air Act
- 1991 – Proposal of New Source Performance Standards (NSPS) and Emission Guidelines (EGs)
- 1996 – Promulgation of NSPS/EGs
- 1999 – Release of EPA's Urban Air Toxic Strategy identifying landfills as a source for evaluation of residual risk
- 2003 - Promulgation of National Emission Standards for HAPs from MSW landfills (requiring bioreactor landfills to provide earlier installation of landfill gas controls)
- 2005 - Release of EPA guidance for evaluating air emissions from older landfills
- 2006 – Release of test method for characterizing area source emissions
- 2007 – Working to provide update to EPA's emission factors for landfill gas emissions

Trends Impacting Landfill Gas Emissions in the U.S.

- Most large landfills have gas collection and control
- Expect continued reliance on landfills for waste discards
- Changes in landfill design and operation such wet/bioreactor operation. Could lead to increased emissions if there is
  - Delay in gas control from onset of liquid additions such as adding liquid to work face,
  - Use of alternative covers or porous materials to promote infiltration,
  - Incorrect sizing of gas capture and control technology, and
  - Flooding of gas wells due to leachate build up.
- Changes in waste composition due to
  - Implementation of recycling & source reduction programs
  - Potential increase in metals due to addition of leachate, sewage sludge, treated wood, and industrial waste
- Potential increased exposure due to urban sprawl and wider use of landfills for recreation or development

EPA's Approach to Quantifying Landfill Gas Emissions

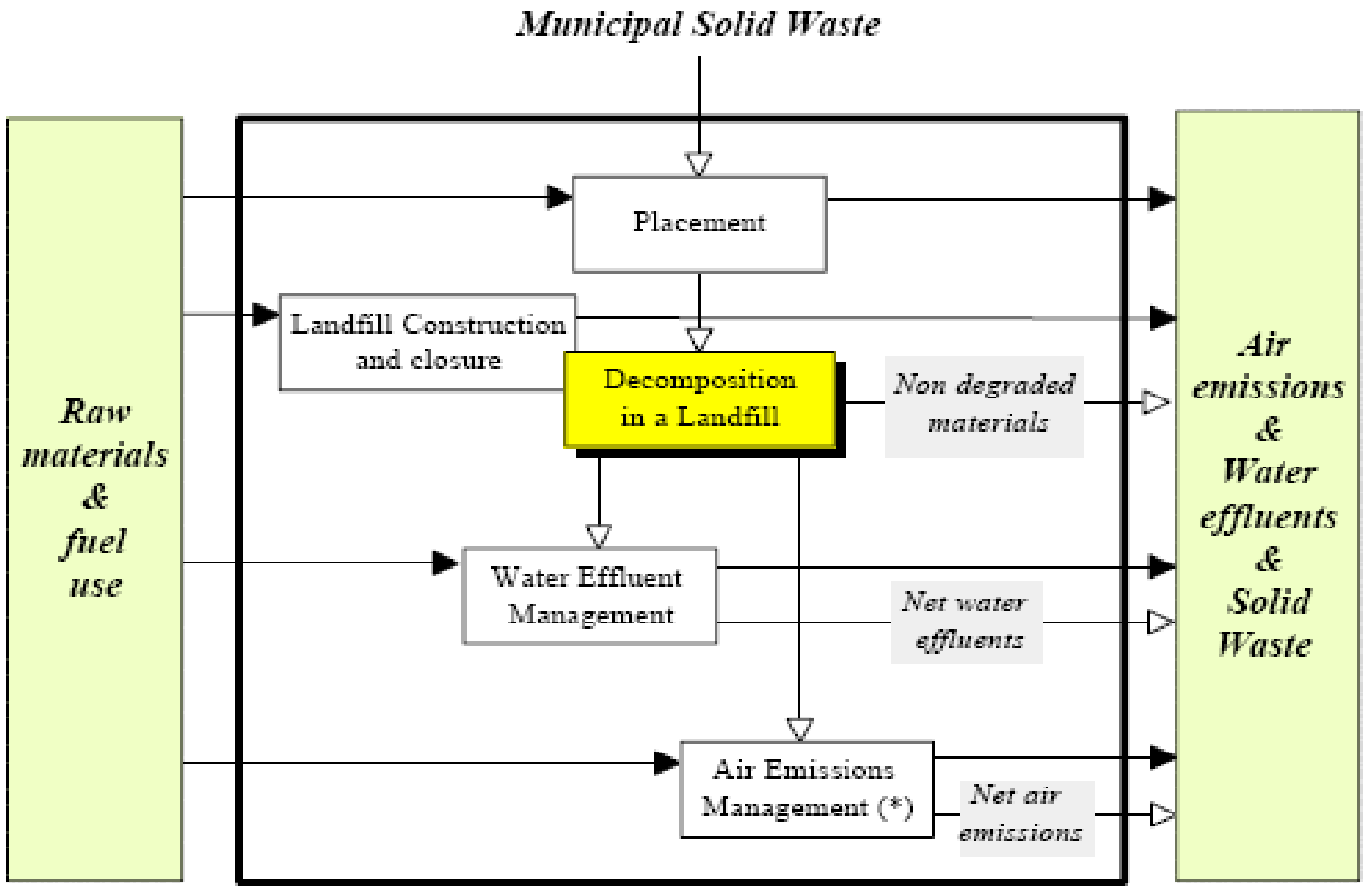
- Use 1st order decomposition rate equation to predict emissions over time.
- Released software for developing emission estimates - EPA's Landfill Gas Emission Model (LandGEM) (Vsn 3.02)
- Different values are recommended in modeling emissions depending upon the use of the estimate
- Defaults for model inputs based on analysis of gas recovery data
- Estimates of gas capture effectiveness are used in determining potential to emit for New Source Review applications



Municipal Solid Waste Decision Support Tool (MSW-DST)

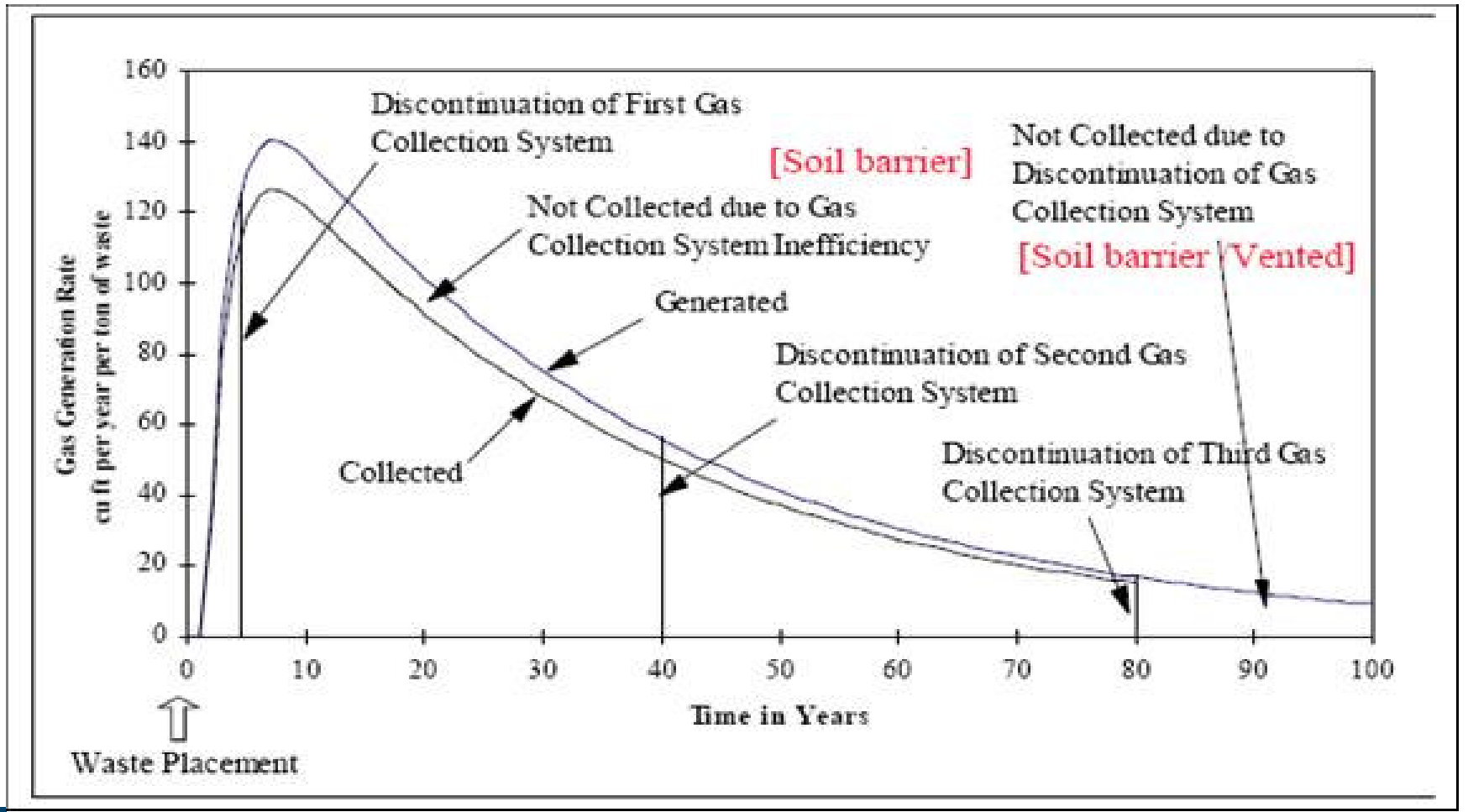
- Provides holistic approach to evaluation of solid waste management
  - Calculates **life-cycle environmental tradeoffs** (multi-media, multi-pollutant) including potential benefits of recycling & energy recovery
  - Cradle-to-Grave - Includes analysis for **all waste management processes** – collection, transportation, recycling, composting, combustion, landfilling
  - Includes capability for **full cost accounting**
  - Includes optimization software for identifying more efficient strategies

Conceptual Life-Cycle Model for Landfills

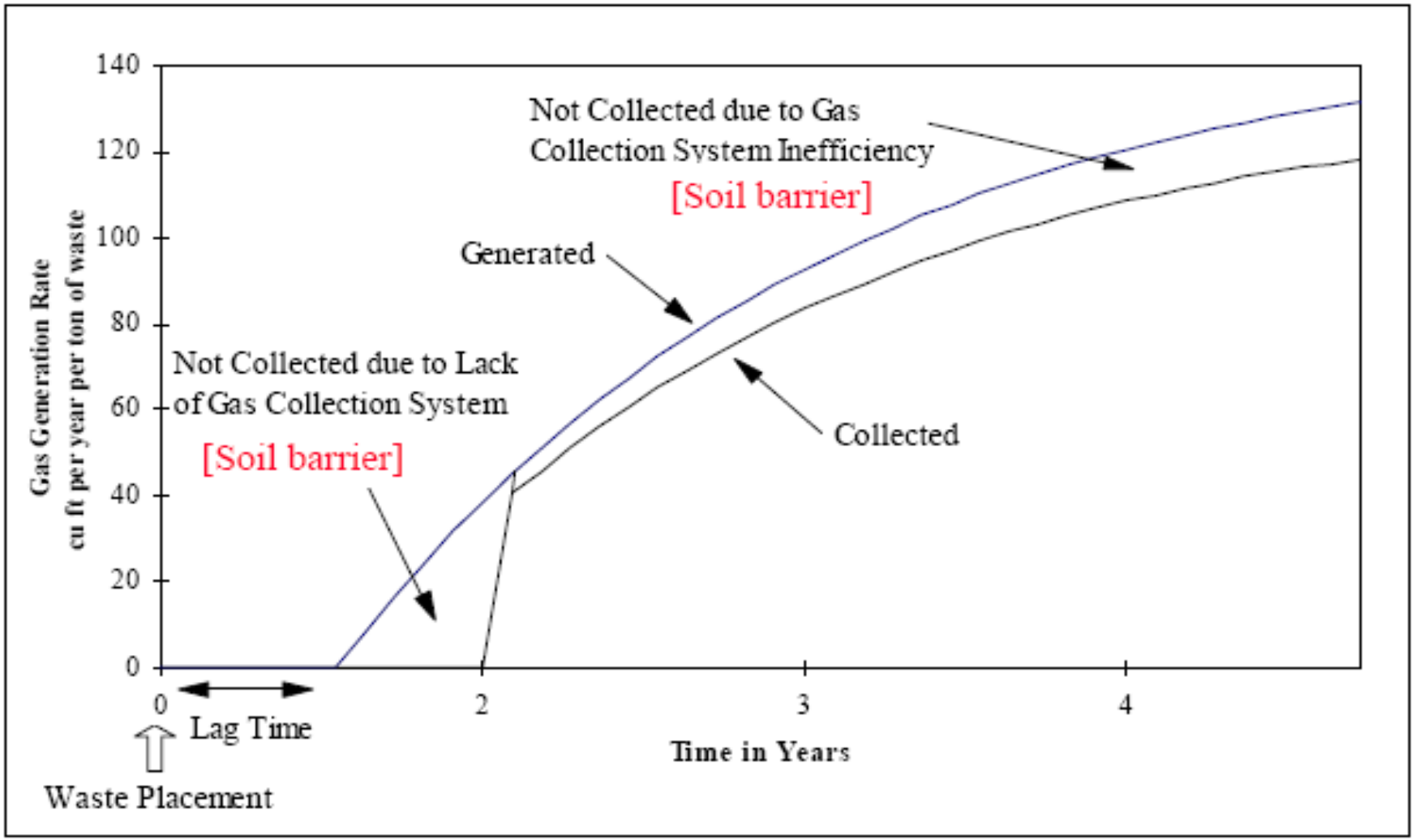


(*) includes energy recovery from methane emissions and the subsequent economies of emissions

Modeling Landfill Gas Emissions Using Life-Cycle Analysis in EPA's Municipal Solid Waste Decision Support Tool

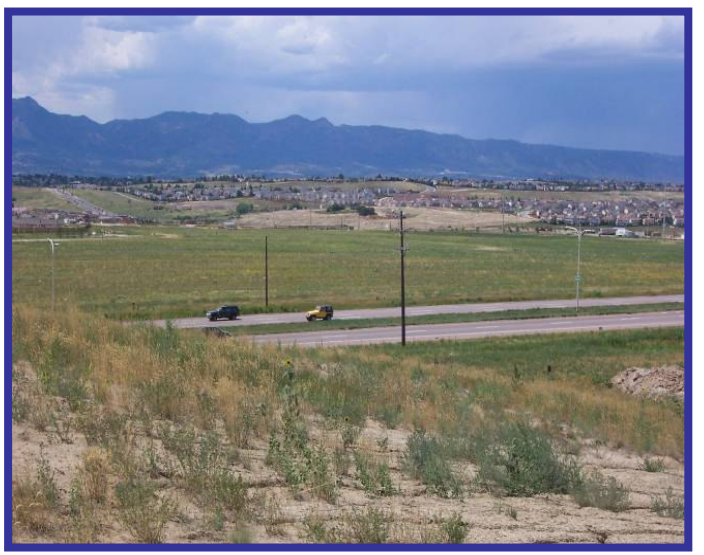


Life-Cycle Modeling of Landfill Gas Emissions – First Four Years after Waste Placement



Measurement Approaches

- Use surface monitoring measurements to determine compliance with Clean Air Act regulations along with conducting monitoring of gas capture and control system
- Released method in 2006 for characterizing area source emissions based on optical remote sensing (ORS) using radial plume mapping (RPM) to identify emission hot spots and quantify uncontrolled emissions
  - Technology is commercially available
  - Also have available software for real-time analysis



Summary on ORS-RPM

- 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 using multiple beam configuration
  - Radial scans detect any potential hot spots
  - Vertical scans determine mass flux
- Research was sponsored by the U.S. EPA's Office of Superfund Remediation and Technology Innovationunder its Monitoring and Measurement for the 21st Century (21M2) initiative.
- For further information on
  - ORS technology - http://www.clu-in.org/programs/21m2/openpath/
  - EPA test method for conducting area source emission measurements– http://www.epa.gov/ttn/emc/prelim.html

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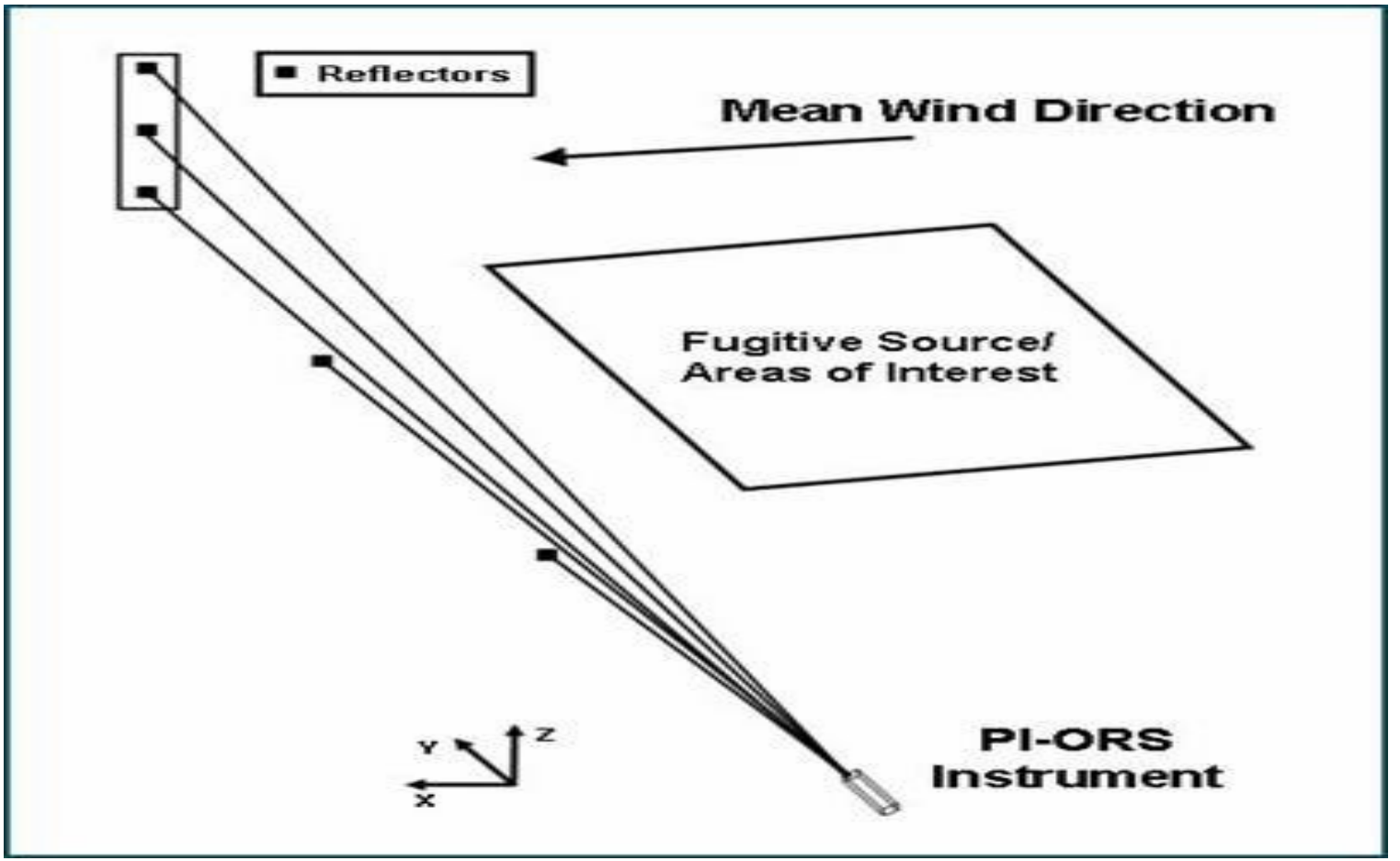
Example Configuration of Vertical Radial Plume Mapping



Horizontal RPM Output from Real-Time Analysis Software

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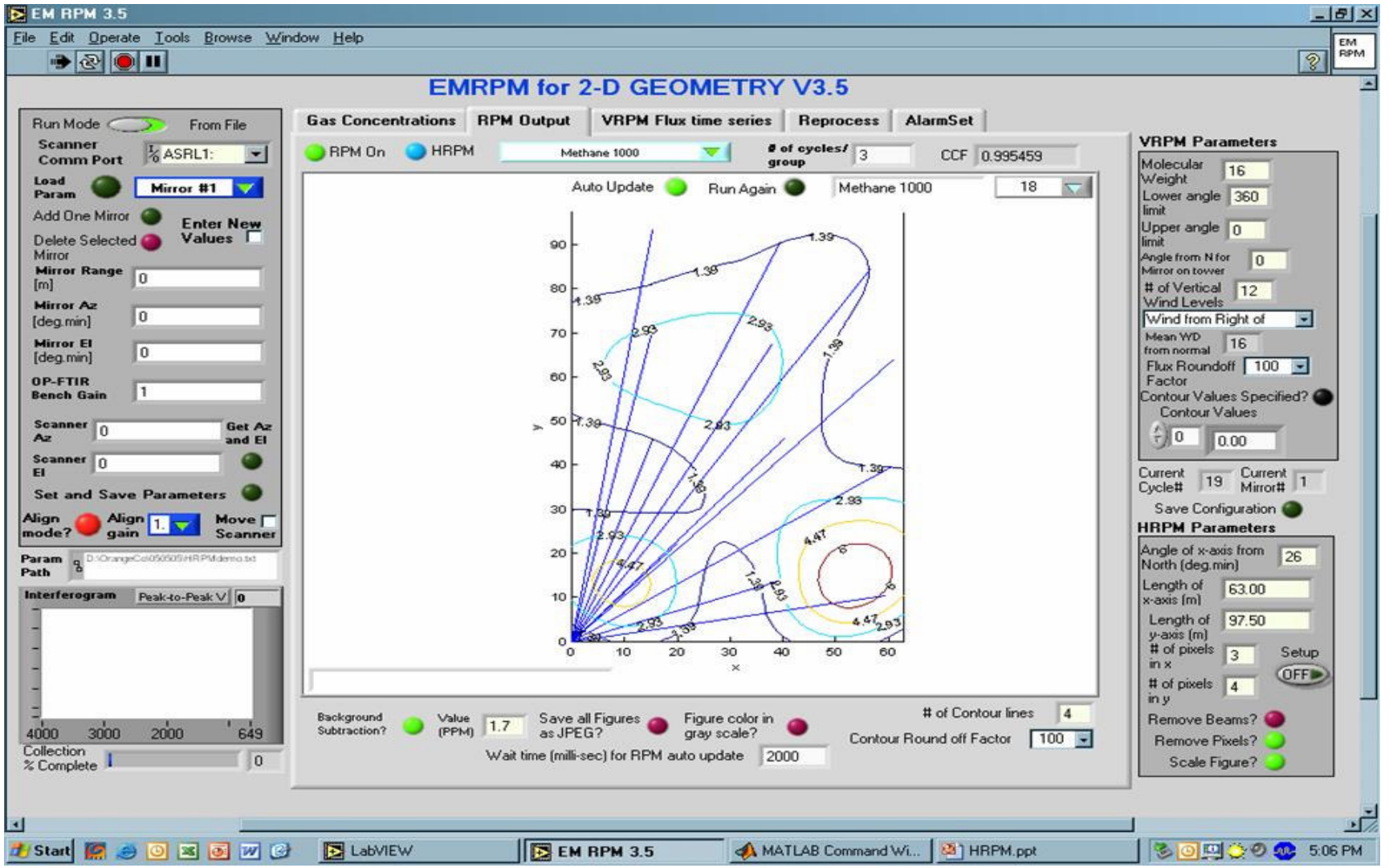
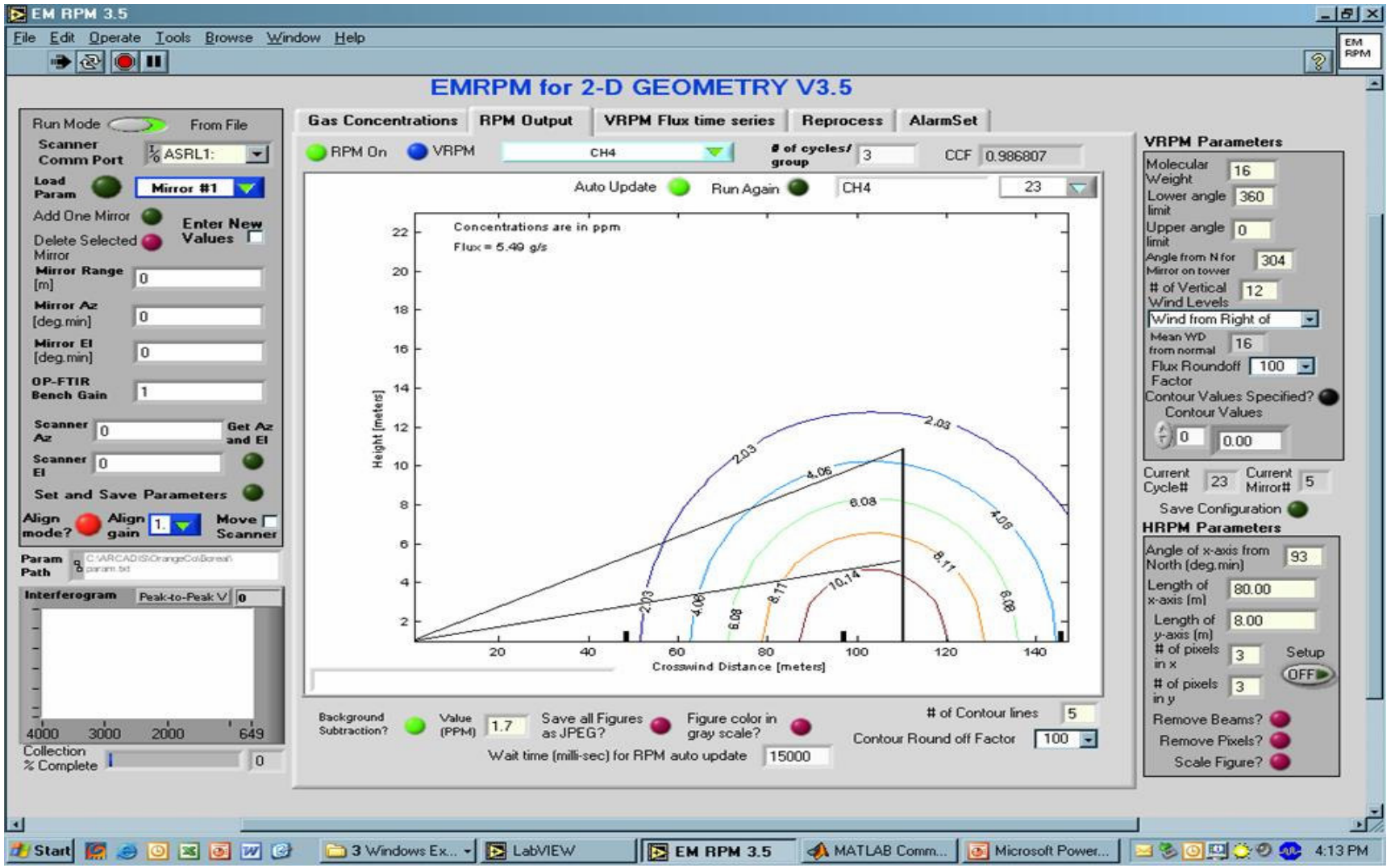


Vertical RPM Output from Real-Time Analysis Software



Recently Completed Projects

- Conducted measurements to evaluate fugitive loss at wet/bioreactor landfills using ORS-RPM
- Compiled gas recovery data from full-scale operating wet/bioreactor landfills
- Completed preparation of guidance for quantifying emissions from older landfills
- Completed measurements of five MSW landfills to provide comprehensive analysis of constituents in raw landfill gas and combustion by-products (report to be released in Spring 2007)
- Compiled data on Hg in landfill gas

Ongoing EPA Activities (Cont.)

- Conducting update of EPA's emission factors to help reduce uncertainty in characterizing landfill gas emissions
  - Will include factors for older landfills, modern sanitary landfills, and wet/bioreactor landfills
  - Will include factors for combustion by-products for different landfill gas control technology
  - Will include data on pollutants not previously included such as organo-mercury and other pollutants of importance to residual risk evaluation
- EPA will be evaluating residual risk based on use of updated emission factors
- Will update LandGEM once updated factors are available

EPA Publications Providing ORS-RPM Data on Landfill Gas Emissions

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 (EPA/600/R-07/032)

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

EPA 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 form 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/ord/NRMRL/pubs/600r05143.

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

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 (Expect to be published by June 07)

Selected Publication List – MSW-DST

Barlaz M.A., Camobreco V., Repa E., Ham R.K., Felker M., Rousseau C. & Rathle J. (1999a) Life-Cycle Inventory of a Modern Municipal Solid Waste Landfill, Seventh International Waste Mgmt and Landfill Symposium, Sardinia 99, Vol III, 337-344, Oct 4-8.

Barlaz M.A., Ranjithan S.R., Brill E.D. Jr., Dumas R.D., Harrison K.W. & Solano E. (1999b) Development of Alternative Solid Waste Management Options: A Mathematical Modeling Approach, Seventh Int. Waste Mgmt & Landfill Symp., Vol I, 25-32, Oct 4-8.

Barlaz, M. A., Kaplan, P. O, S. R. Ranjithan and R. Rynk, 2003, "Evaluating Environmental Impacts of Solid Waste Management Alternatives, Part I", Biocycle, Sept., p. 60 - 66.

Barlaz, M. A., Kaplan, P. O, S. R. Ranjithan and R. Rynk, 2003, "Evaluating Environmental Impacts of Solid Waste Management Alternatives, Part II" Biocycle, Oct., p. 52 - 56.

Ecobalance (1999) *Life-Cycle Inventory of a Modern Municipal Solid Waste Lan*dfill; Prepared for the Environmental Research and Education Foundation, Washington, D.C.

Ham R.K. & Komilis D. (2003) *A Laboratory Study to Investigate Gaseous Emissions and Solids Decomposition During Composting of Municipal Solid Waste*, EPA-600/R-03/004.

Harrison K.W., Dumas R.D., Solano E., Barlaz M.A., Brill E.D. & Ranjithan S.R. (2001) Decision Support Tool For Life-Cycle-Based Solid Waste Management, *Journal of Computing In Civil Engineering*, Jan.

Selected Publication List – MSW-DST (Cont.)

Jambeck, J., Weitz, K.A., Solo-Gabriele, H., Townsend, T., Thorneloe, S., (in press). CCA-treated Wood Disposed in Landfills and Life-cycle Trade-Offs With Waste-to-Energy and MSW Landfill Disposal, *Waste Management* special edition.

Kaplan, O.; Ranjithan S.R.; Barlaz M.A. (2006) The Application of Life-Cycle Analysis to Integrated Waste Management Planning for the State of Delaware, Prepared for Delaware Solid Waste Authority, May.

Solano E., Ranjithan S.R., Barlaz M.A., Brill E.D. (2002a) Life-Cycle-Based Solid Waste Management. I. Model Development, Journal of Environmental Engineering, October.

Solano E., Dumas R., Harrison K., Ranjithan S.R., Barlaz M.A., & Brill E.D. (2002b) Life-Cycle-Based Solid Waste Management. II. Illustrative Applications, J. of Environmental Engineering, October.

Thorneloe, S.A., Weitz; K.A; Jambeck, J. (2006) Application of the U.S. Decision Support Tool for Materials and Waste Management, Int. *Waste Management* special edition (In Press).

Thorneloe S.A., Weitz K.A., Barlaz M. & Ham R.K. (1999a) Tools for Determining Sustainable Waste Management Through Application of Life-Cycle Assessment: Update on U.S. Research, Sardinia 99, 7th International Landfill Symposium, Vol V, 629-636, Oct 4-8.

Selected Publication List – MSW-DST (Cont.)

Thorneloe S.A. & Weitz K.A. (2001) U.S. Case Studies using MSW DST. Proceedings Sardinia 2001, 8th Int. Waste Management & Landfill Symposium, Cagliari.

Thorneloe S.A. & Weitz K.A. (2003) Holistic Approach to Environmental Management of Municipal Solid Waste. Proceedings Sardinia 2003, 9th International Waste Management and Landfill Symposium, CISA publisher, Cagliari.

Thorneloe, S.A. & Weitz K.A. (2004) Sustainability and Waste Management. Proceedings from Sustainable Waste Management, Waste Management Association of Australia, Nov 24-26, 2004, Melbourne, Australia.

US EPA (2006) Application of Life-Cycle Management to Evaluate Integrated Solid Waste Management Strategies, **https://webdstmsw.rti.org**.

Weitz K.A., Thorneloe S.A., Nishtala S.R., Yarkosky S. & Zannes M. (2002) The Impact of Municipal Solid Waste Management on GHG Emissions in the United States, Journal of the Air and Waste Management Association, Vol 52, 1000-1011.

Weitz, K.A. (2003) *Life-Cycle Inventory Data Sets for Material Production of Aluminum, Glass, Paper, Plastic, and Steel in North America*, **https://webdstmsw.rti.org**.

Conclusions

- Ongoing research will help in reducing uncertainties associated with quantifying LFG emissions including evaluating
  - Conventional Landfills,
  - Wet/Bioreactor Landfills, and
  - Older Landfills.
- Will result in more credible, up-to-date data
- Will use results to update
  - Landfill Gas Emission Factors (AP-42)
  - LandGEM
  - MSW-Decision Support Tool