Greenhouse Gas Inventories for the Waste Industry: The Importance of Measuring Landfill Gas Total Emissions

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Introduction

Over the past twenty years, scientific studies have shown a significant increase in atmospheric concentrations of carbon dioxide (CO_2) and other greenhouse gases (GHG) that trap heat in the Earth's atmosphere. Large segments of the scientific community agree that the Earth is getting warmer faster and that human activities, primarily burning of fossil fuels and land use changes, play a significant role in the increase in GHG concentrations. How the U.S. addresses this risk will be one of the most significant public policy challenges the waste industry will face at the federal, state, and local levels of government.

Democratic majorities in the U.S. Congress are building momentum for federal climate change legislation in the next several years. In only two months, four bills have been introduced (three in the Senate and one in the House) and a fifth piece of draft legislation has been circulated in the Senate. However, in absence of federal legislation, many states, such as California, have or are initiating climate action plans aimed at inventorying GHG emissions in their area and instituting mandatory policies to reduce emissions over time. These emerging programs present both opportunities and challenges for the waste management industry.

Nine northeastern states and California are the most advanced in developing regulatory schemes to inventory, cap and trade GHG emissions. While the northeast is focused on regulating GHG emissions from electric utilities, California, under its recently passed Global Warming Solutions Act, may choose to regulate MSW landfills. According to the March 2006 California Climate Action Team report prepared for the Governor and Legislator, landfills were one of five source categories identified as significant. A waste industry group recently formed with the objective of developing accurate and representative greenhouse emissions quantification protocols for waste management activities not just for reporting requirements in California but in anticipation of national emissions reporting initiatives.

A number of protocols have been established to meet international or national requirements for estimating landfill emissions. Because these are the only protocols now in existence they are likely to be applied if new methods are not developed. Key problems with these protocols include use of default values for methane oxidation that do not reflect the effects of various types of landfill cover and climate, and failure to account for sequestered carbon in the landfill.

One of the risks is that the protocols currently used for developing GHG emissions inventories from landfills at the national level, the modeling of gas generation based on the amount of waste present, would be applied to individual landfills. This approach may not give sufficient credit to landfills where the gas is aggressively collected and used as an energy source, and would likely result in overestimates of greenhouse gas emissions at some landfills. Under a GHG inventory scheme in which every pound of carbon emitted, converted to energy, flared or sequestered will have economic consequences, an accurate method of inventorying GHG emissions must be adopted.

Waste Management (WM), with over 340 landfills in the U.S., is the nation's largest landfill owner. WM has embarked on a major research program to develop measurement techniques necessary to quantify methane emissions from their landfills . The resulting information will encourage landfill design and operational practices that reduce methane emissions. WM is using state-of-the-art techniques that were not available even five years ago. In this paper, we describe the measurement techniques, the program objectives and initial results from work completed in 2006.

Nationally, it is a particularly attractive strategy to reduce methane emissions. Methane is by 20-fold a more powerful greenhouse gas than carbon dioxide. In comparison to carbon dioxide, the concentration of methane in the atmosphere is only 0.5%, yet it's contribution to greenhouse warming is 25%. Methane's atmospheric lifetime is only one tenth that of carbon dioxide, 10 as opposed to 100 years, so the effect of mitigation strategies would result in a quick payoff in reducing the amount of methane in the atmosphere. Indeed, recent measurements have shown that the rapid increase in atmospheric methane observed in the late 1980's has abated, and there exist the potential to actually lower the atmospheric burden of the powerful greenhouse gas. Emerging programs may allow landfill owners who voluntarily collect and control landfill methane to sell GHG reduction offsets in a carbon trading market.

Project Scope

The overall goal of WM's research program is to measure landfill gas (LFG) emissions under a wide variety of conditions:

- slopes and flat surfaces
- daily cover on an active working face
- intermediate cover
- final cover (with and without a geomembrane)
- seasonal variations in methane oxidation and capture efficiency

Ultimately, WM wants a database that describes methane emissions over the range of conditions one finds at both operating and closed landfills. This will make it possible to predict emissions from operating and proposed landfills with field-validated numbers instead of uncertain models. In 2006, the project team conducted field measurements at both a conventional Subtitle D landfill (Springhill in Campbellton, Florida) and a bioreactor landfill (Outer Loop in Louisville, Kentucky). In 2007 and 2008, they will conduct tests at five WM landfills throughout the U.S. The WM team will test each of these landfills based on cover type and season. Several of these facilities have more than one cover type. Ultimately the testing program will evaluate a minimum of ten cover types over a minimum of two seasons.

WM has made a major commitment to this work, having purchased state of the art instrumentation and committing research scientists and engineers to the project nearly full time for perhaps six months of each year. Over a three year period, they expect to spend about two million dollars on this effort, a cost well worth the investment to definitively measure surface emissions, methane oxidationrate, and methane collection efficiencies.

Measuring Surface Emissions Using Laser Technology

The largest difficulty in obtaining reliable measurements of fugitive methane loss is its extremely spotty nature, i.e. the top of a landfill is hardly uniform. But WM researchers are adopting a method developed by ARCADIS, to use an infrared laser (Figure 1) to measure methane gas escaping the landfill surface.

Figure 1. WM's Roger Green aligns laser beam with mirror.

The method uses a tunable diode laser (TDL) from Boreal Laser Ltd. that takes advantage of the fact that methane absorbs strongly in the infrared light region (that's what makes it a powerful greenhouse gas). To estimate surface emissions, the methane concentration is combined with wind speed and direction in a computer model to calculate the mass of methane emitted from a selected area.

How does Laser Technology Work?

To begin, the team carefully places a series of mirrors across and above the landfill surface to form a 3-dimensional set of reflectors. The laser is programmed to move from mirror to mirror, shining its light at each mirror in turn. The laser beam bounces back from the mirror to a receiver that measures the signal strength. The reduction of the laser beam's intensity is proportional to the amount of methane along that pathway. Essentially, an entire portion of a landfill surface is placed within a giant open path spectrophotometer! The data and mirror positions are input to a computer in the field (Figure 2). This arrangement of laser and mirrors and their orientation to the wind is illustrated in Figure 3. By summing the laser-mirror pathways and the concentration of methane along them, horizontal and vertical maps of the methane plume above the landfill can be depicted (Figure 4 and 5). Now factor in the wind speed and direction and you have an estimate of the rate at which the methane escapes the landfill.

Figure 2. Doug Goldsmith from Alternative Natural Technologies checks mirror positioning with computer.

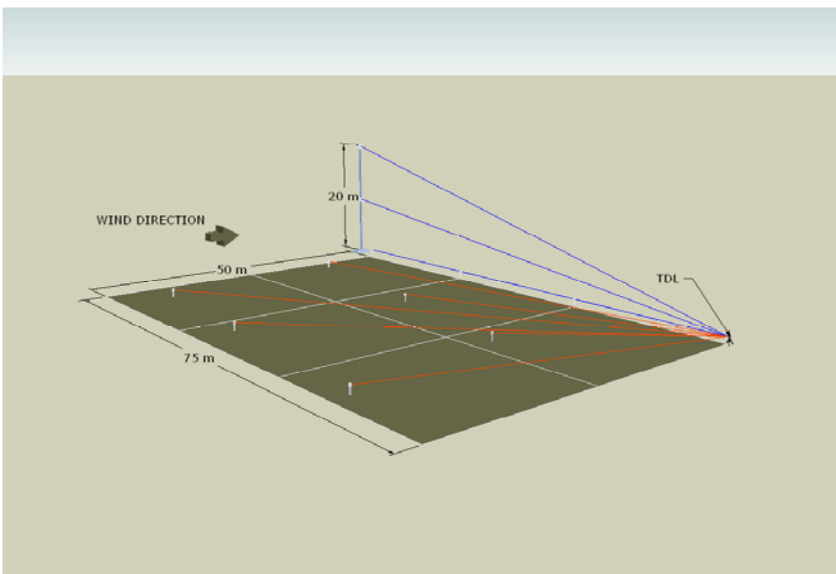

Figure 3. Scheme of the arrangement of mirrors, laser, landfill plume and wind direction.

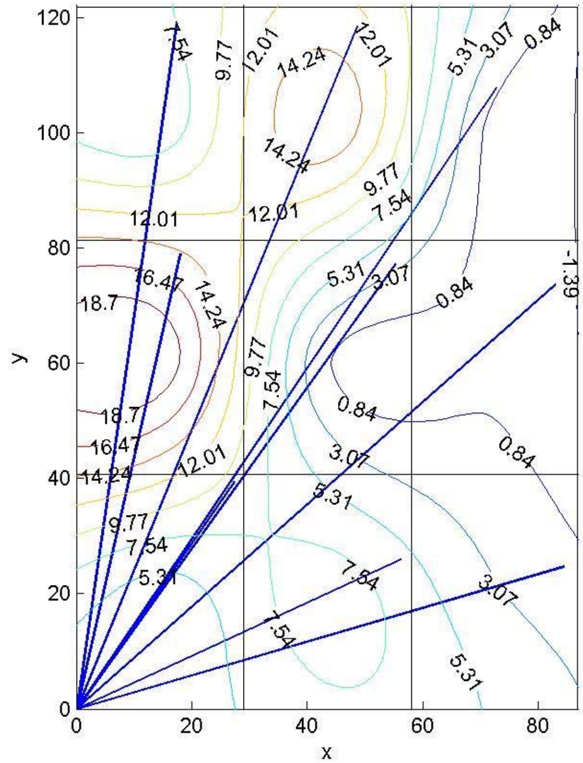

Figure 4. Horizontal map of methane concentrations within the air at a height of 0.3 meters above the landfill. The map integrates methane escape from both from the soil and from well casings and leachate circulation injection pipes.

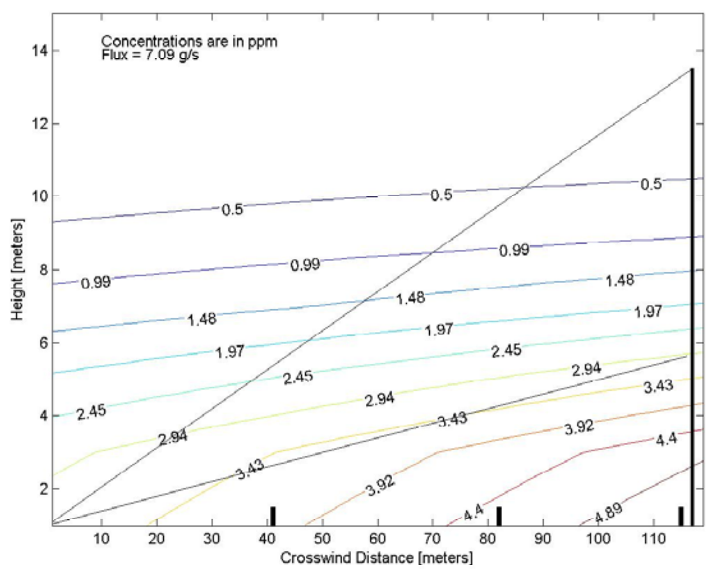

Figure 5. Vertical distribution of methane in the air above the landfill cover

Checking and Cross-checking

Because the laser approach is so new, it is being subjected to rigorous testing and comparison. The WM team made simultaneous measurements of methane emissions using the new laser approach and crosschecked it with a more traditional approach, static chambers. The chamber approach involves installing a frame into the soil and then returning later to place a chamber lid upon this frame. By placing the frame first, disturbance to the soil is minimized during the measurement period. To measure emissions, samples of air from the closed interior are collected over a 20 minute time period and monitored for the evolution of methane. In this study, we used chambers that were fairly small, about 4 square feet, but we used a lot of them. Day after day we set out 72 chambers over a grid pattern that encompassed the area measured by the laser. Chamber measurements were made once daily over the test period while the laser measurements were made continuously over a 3 to 6 hour period.

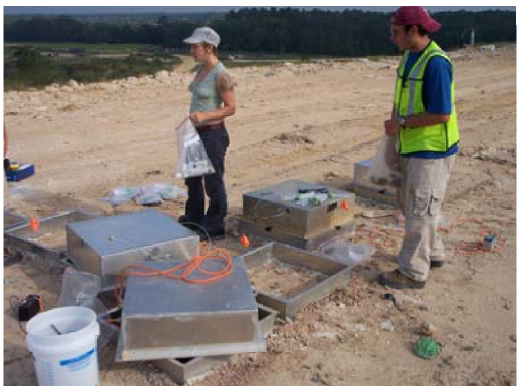

Figure 6. Students from Florida State University carried out chamber based flux measurements.

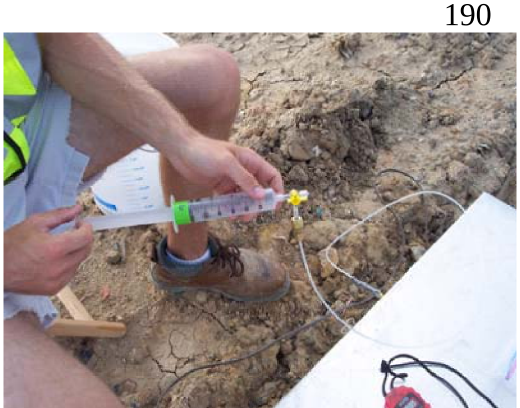

Figure 7. Sampling gas from within the chamber.

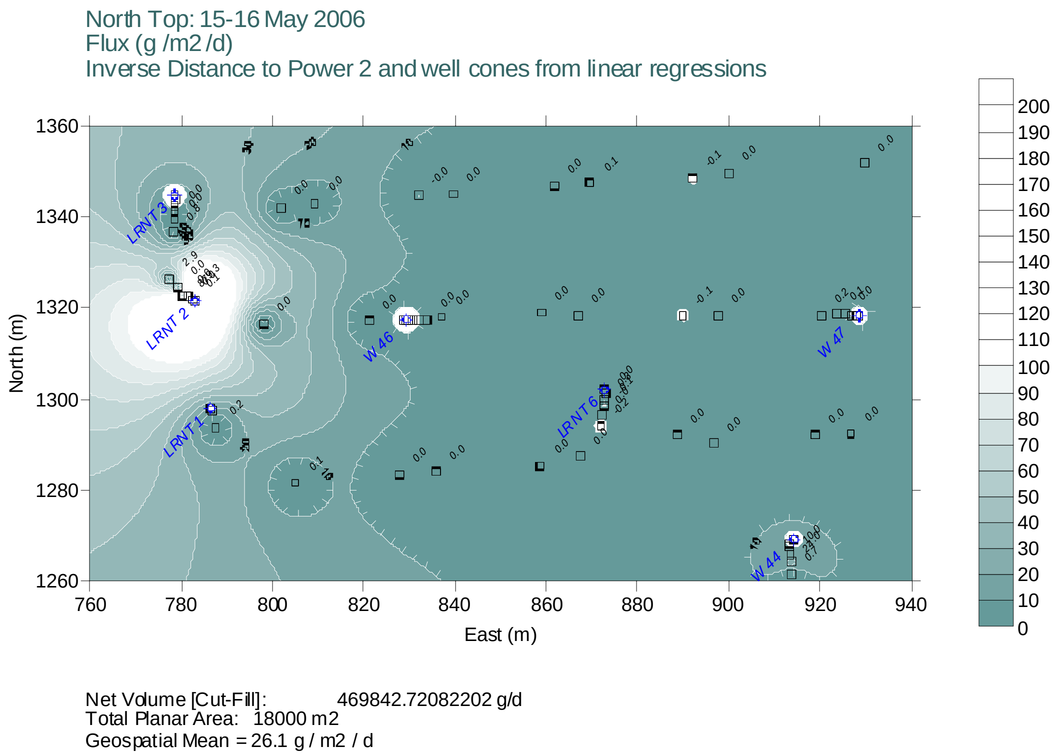

Figure 8. Contour plot of methane emissions from chamber based measurements at the Springhill landfill. The geospatial mean of the methane emission rate was 26 g m^{-2}d^{-1}. The cover has a geomembrane overlain by overlain by 2 feet of clay. Emissions were focused about leachate circulation wells, an easily solvable problem.

For this report, work was conducted on a closed section of the Spring Hill Landfill. The section of the cover that was tested includes a geomembrane overlain by 2 feet of clay. The cover is seeded and there is an active gas collection system in place. Individual chamber measurements were mostly below detection but occasionally were as high as 9000 g CH_4 m^{-2} d^{-1}. Elevated emissions were due to punctures in the geomembrane cover and were centered around leachate injection wells and gas extraction wells. (Figure 8). These emissions are easily repaired as part of the landfill's routine monitoring and maintenance activity. Emissions from the actual cover surface were non-detectable. The data were contoured in Surfer and the geospatial mean flux determined to be 26 g CH_4 m^{-2}d^{-1} (Figure 8).

Taking the 4.8 g/s estimate derived from the laser data and extrapolating it to the footprint area of the surface of the landfill (23000 m^2) produces a value of 18 g CH_4 m^{-2}d^{-1} The two approaches agreed within 30%.

In addition to determining methane emissions by these two approaches, estimates of soil methane oxidation are also being determined. Combining the emission and oxidation estimates with measurements of methane captured by the gas extraction system allows determination of

- a complete carbon balance and
- the methane capture efficiency independent of the Landgem model

In conclusion, our results indicate that landfill covers work – we observed low emissions from covered areas. Emissions were associated with hot spots around penetrations (gas wells, leachate injection pipes) and these are easily fixed. Finally, we propose that by using a combination of measurement tools, the actual GHG emissions can be used to better calibrate our predictions of landfill gas collection system efficiency.

Possible Quotes:

Jeff Chanton Ph.D., FSU – The research is a massive effort that should result a much better idea of the carbon cycle in the industry.

Gary Hater, WM –While TDL is still a research tool there is hope that the equipment will be refined enough to make it routinely practical some day.

Morton Barlaz Ph.D.,NCSU – The potential to develop flux measurements over a large area instead of many discrete small surfaces will provide great benefits to the air science surrounding landfills