Impact of Changes in Barometric Pressure on Landfill Methane Emission

Liukang Xu[1]*, Xiaomao Lin[1], Jim Amen[1], Karla Welding[2], and Dayle McDermitt[1]
[1] LI-COR Biosciences, Lincoln NE 68504
[2] Bluff Road Landfill, City of Lincoln, Lancaster County, NE 68517
* liukang.xu@licor.com

INTRODUCTION

Methane plays a critical role in the radiation balance and chemistry of the atmosphere. Globally, landfill methane emission contributes about 10 - 19% of the anthropogenic methane burden into the atmosphere [Bogner and Matthews, 2003; IPCC, 2007]. In the United States, as much as 37% of annual anthropogenic CH_4 emissions come from landfills [Czepiel et al., 2003], which represents the largest source of anthropogenic methane emissions [Bogner and Matthews, 2003].

Four methods that are commonly used to quantify landfill methane emissions are inventory, chamber-based, trace plume, and mass balance. These methods provide methane emission snapshots with poor temporal resolution due to high labor requirements and lack of the capability for automated measurement.

Because of its capability for continuous measurements, the eddy-covariance method was used in this study to understand the impact of changes in barometric pressure on landfill methane emissions.

Figure 1. Site information and instrumentation. The study site at the Bluff Road Landfill, which is located north of Lincoln, NE (40.908°N, 96.638°W, 367 m above sea level). The instrument station was located near the middle of a relatively flat plateau of the landfill. Based on its design drawing, the waste depth at the capped area ranged from 18 to 40 m. Emissions of CH_4 and CO_2 were measured continuously with the eddy-covariance method since June 2010. The instruments (Gill sonic, LI-7700 open-path methane analyzer, and LI-7500A open-path CO_2/H_2O gas analyzer) were mounted 3 m above the ground.

REFERENCES

– Bogner J., Matthews E. 2003. *Global Biogeochemical Cycles*. 17:1065.

– Czepiel P.W., et al. 2003. *Waste Management*. 23:593.

– IPCC, 2007. Fourth Assessment Report of the IPCC; Summary for Policymakers.

– Torrence, C., Compo G. P. 1998. *Bulletin of the American Meteorological Society*. 79:61.

LI-COR
www.licor.com

© 2013 LI-COR, Inc. Presented at NACP 2013. LI-COR is a registered trademark of LI-COR, Inc., in the United States and other countries. All other trademarks belong to their respective owners.

LI-COR is an ISO 2001 registered company.

RESULTS & DISCUSSION

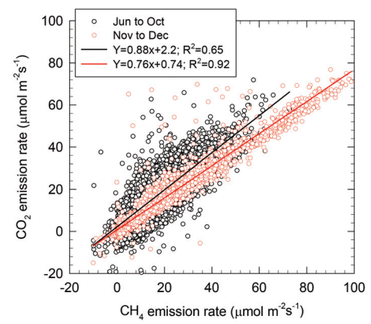

Figure 2. During the cold season (from Nov to Dec), the CO_2 and CH_4 emission rates correlated very well with a slope of 0.76 and R^2 of 0.92. At low temperatures, we expect that soil CO_2 respiration and CH_4 oxidation in clay soil were reduced, especially when the air temperature was below 0 °C. Our gas samples extracted from the landfill show that it contained 41.3% of CO_2 and 54.4% of CH_4, which yields a ratio of 0.76. This shows the validity and reliability of our methane emission data.

In the warm season (from Jun to Oct) the relationship between the CO_2 and CH_4 emission rates had a slope of 0.88 (R^2 = 0.65), higher than that from the cold season. This is probably due to higher soil CO_2 respiration and higher oxidation rate of CH_4. Diurnal varia- tion in photosynthetic CO_2 uptake by leaves from vegetation grown on the cover soil may also play a role.

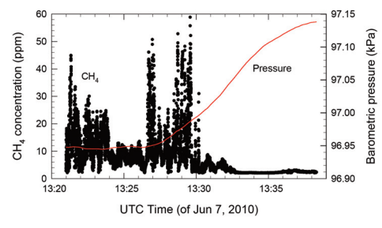

Figure 3 illustrates how quickly the atmospheric methane concentration at the landfill responded to changes in barometric pressure. Note that for this event the barometric pressure increased from 96.95 kPa at 13:27 to 97.13 kPa at 13:37, about 0.18 kPa increase in 10 minutes, a change rate of 1.08 kPa hr^{-1}. This was relatively high *dP/dt*, as *dP/dt* we normally saw were in the range of ± 0.1 kPa hr^{-1}.

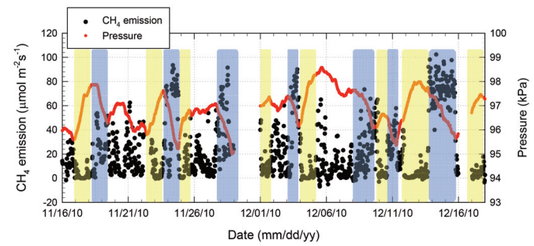

Figure 4. Response of methane emission rates to changes in barometric pressure. The dataset obtained is from November 16 to December 18. Whenever atmospheric pressure increased (light yellow shaded periods), emission rates were strongly suppressed, and whenever barometric pressure decreased (light blue shaded periods), emission rates were strongly enhanced. This phenomenon occurred repeatedly.

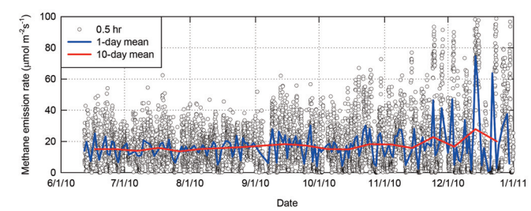

Figure 5. Large variations in hourly (open black circle), 1-day mean (solid blue line), and 10-day mean (solid red line) methane emission rate. The mean methane emission over the entire experiment was 17.7 μmol $m^{-2}s^{-1}$. The variation of daily mean emission was larger in the cold season than in the warm season; for example, the daily mean emission rate on December 21 was only 1.79 μmol $m^{-2}s^{-1}$. On the very next day (December 22) the mean rate was as high as 63.78 μmol $m^{-2}s^{-1}$, a 35.6-fold increase. When we averaged the hourly emission rate into 10-day means, little variation can be seen for the data from the warm season, probably because the impact of changes in barometric pressure on the landfill methane emission was averaged out.

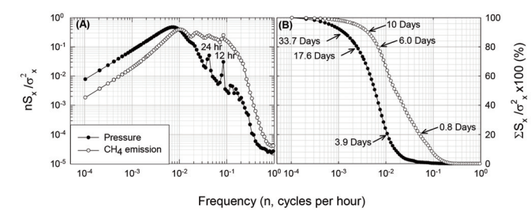

Figure 6. Power spectra (A, S_x) and ogive curves (B, $\sum S_x$) for the time series of barometric pressure and landfill methane emission rate. Both power spectral densities are normalized by their total variances (σ_x^2) and also weighted by the natural frequency (n). Ogive curves are integrated from high to low frequency, and plotted as a percentage of total variance. Arrows on two ogive curves indicate various lengths of measurement needed to capture 20%, 80% or 90% of total variance. From the ogive curve, one would need 10-day continuous measurement to capture 90% of total variance for methane emission rate.

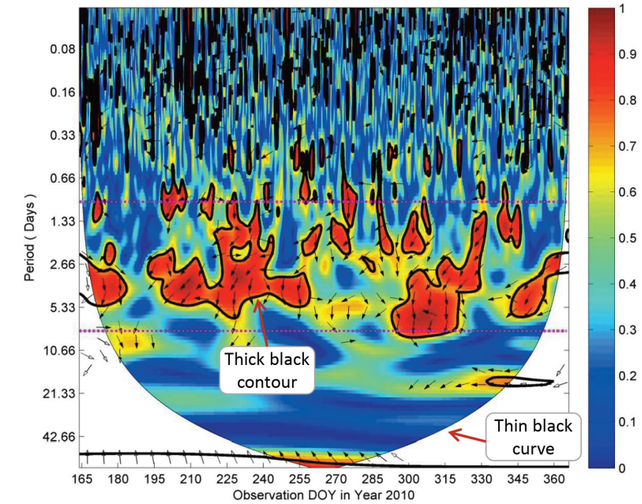

Figure 7. Analysis of squared wavelet coherence between barometric pressure and methane emission time series. Different colors represent the values of coherence between pressure and the methane emission. The thick black contours represent 5% significance level against the red noise (*Torrence and Compo*, 1998). The phase angles between the two time series are represented by directions of arrows, with increasing phase angle in the clockwise direction. Arrows pointed to the right indicate that the phase angle is 0°, which means that the two time series are in phase; arrows pointed downward mean that the phase of pressure variation leads the methane emission by 90°, and so on. The thin black curve is the cone of influence which will occur at the beginning and end of the wavelet power spectrum (*Torrence and Compo*, 1998). This result shows that the barometric pressure and methane emission are neither in phase nor out of phase, but that the barometric pressure leads the methane emission by 110.7° on average for cycles of 1 day to 8 days. The high coherence with a constant phase angle between two time series demonstrated the cause-and-effect relationship. This result is consistent with results presented in Figure 4.

CONCLUSIONS

- Landfill F_{CH4} was strongly dependent on *dP/dt*; rising barometric pressure suppressed the emission, while falling barometric pressure enhanced the emission.
- There was up to a 35-fold variation in day-to-day methane emissions due to changes in barometric pressure.
- Wavelet coherence analysis showed a strong coherency between variations of *P* and F_{CH4} at the periodicities ranging from 1 day to 8 days.
- Estimates of annual total landfill methane emissions based on trace plume method, mass balance method, or closed-chamber method will inevitably yield a large uncertainty.
- Our results demonstrate the need for continuous measurements to quantify the annual total landfill emission.