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UNCERTAINTY ESTIMATE FOR OPEN-PATH REMOTE SENSING OF FUGITIVE EMISSIONS

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ABSTRACT

Open-path remote sensing techniques such as Fourier transform infrared (FTIR) spectrometry offer a powerful approach for determining emission rates from line and area pollution sources. Typically, a photon beam downwind of the source intersects the pollutant plume, and a characteristic such as optical absorption is measured. The path-integrated concentration is calculated from this measurement. The emission rate can then be estimated using a tracer gas reference or by dispersion modeling.

Open-path monitoring has important advantages over conventional methods for measuring fugitive emissions. However, a different set of design and quality assurance (QA) considerations must be addressed in developing the measurement and data analysis protocols. Failure to consider the method's unique characteristics can impair the accuracy and precision of the results obtained from the calculation of fugitive emissions. This paper will discuss the following quality-related issues, which were found to be critical in calculating fugitive emissions:

- length and location of the optical path relative to the source,
- placement of the tracer gas release point, and
- meteorological measurements.

INTRODUCTION

The Air Pollution Prevention and Control Division (APPCD) conducted a greenhouse gas (GHG) measurement program during the summer of 1995. The purpose of this program was to develop a better estimate of GHGs being emitted from anaerobic lagoons commonly used for the treatment of human, animal, and industrial wastes. This measurement program was undertaken by EPA because of the scarcity of field measurements to confirm estimated GHG emission rates from these sources. Data from the program can also be used to estimate the level of uncertainty that can be assigned to these emission rates.

The APPCD Quality Assurance Staff conducted an audit at one of the GHG measurement sites, a waste water treatment facility in Texas. The waste water treatment facility, shown in Figure 1, included one aerobic and four anaerobic lagoons. The anaerobic lagoons were approximately 200 by 300 feet, aligned north to south. The total anaerobic lagoon area, including berms between and around the lagoons, was approximately 1000 by 350 feet. The FTIR beam was 570 feet long and was placed 175 feet downwind of lagoon No. 4. Only the anaerobic lagoon emissions were measured at this site.

The tracer gas reference technique was used to estimate emission rates. The auditors utilized a second tracer gas to assess the effects of location, wind speed, and direction on the calculated emission rates. This paper presents the results of the audit, as they relate to the open-path FTIR method.

METHODS

The GHG emission estimates were determined using open-path FTIR, supplemented by tracer gas (SF_6) releases and meteorological measurements. SF_6 was released from between lagoons No. 2 and 3, as shown in Figure 1. The emission rates for GHGs (ER_{GHG}) were calculated from the known SF_6 release rate (ER_{SF6}). The measured concentrations of GHGs (C_{GHG}) and SF_6 (C_{SF6}) were determined as shown in equation (1):

$$ER_{GHG} = \frac{ER_{SF6} * C_{GHG}}{C_{SF6}} \qquad \textbf{(1)}$$

The FTIR was operated continuously, but valid data were acquired only when the meteorological conditions were acceptable. Meteorological equipment was also installed and operated at the site. Acceptable meteorological conditions were defined by the wind speed and direction. Wind speed indicated that there was sufficient mixing of the plume, and wind direction indicated that the entire plume was captured by the FTIR beam. The acceptable meteorological criteria had been defined before beginning the field measurement program.

The audit evaluated the FTIR data by release of an audit tracer gas that was different than the tracer gas used and not emitted by the lagoons. The audit tracer gas was released to the atmosphere through a dry gas meter connected to a rotameter. The rotameter was used to set the approximate release rate and the exact release rate was calculated from the change in volume over time, as indicated by the dry gas meter. The audit tracer release rate was maintained nearly constant during the audit. The average release rate from all five locations was calculated to be 0.5 g/sec with a coefficient of variation of 9.7%.

Audit tracer gas was released from five locations within the waste water treatment lagoon area: four corners and the center *(SE, SW, CTR, NE, NW)*. Audit tracer gas was released from only one point at a time. The release rate of the audit tracer gas was known only to the auditors. The emission rate of audit tracer gas was calculated using equation (1), the same equation used to calculate the GHG emissions. The calculated emission rate of audit tracer was then compared to the known release rate.

RESULTS

It was found that releasing the audit tracer gas as near as possible to the SF_6 release location *(CTR)* resulted in good agreement between the calculated emission rates and the known release rates. The FTIR beam was located downwind (North) of all the release points. Therefore, the release points on the upwind side (*SE & SW*) were farthest from the IR beam; the downwind points (*NE & NW*) were nearest the IR beam. Releases from points upwind of the SF_6 release location (*SE & SW*) were biased low. Releases from points downwind of the SF_6 release location (*NE & NW*) were biased high. The variability of the downwind locations was also markedly larger than for releases upwind, both on absolute and relative bases. These data are summarized in Table 1.

Table 1. Results of Audit Tracer Gas Measurements

Location	Number of Valid Observations	Calculated Audit Tracer Emission Rate g/sec	Bias*	Std. Error of Estimate for Audit Tracer Emission Rate g/sec(%)
Center (CTR)	5	0.49	-2.0%	0.044 (9%)
Upwind (SE)	12	0.32	-36%	0.178 (13%)
Upwind (SW)	3	0.19	-62%	0.007 (4%)
Downwind (NE)	7	8.8	+1660%	3.32 (38%)
Downwind (NW)	4	1.5	+200%	0.37 (25%)

*Bias is calculated assuming an average audit tracer gas release rate of 0.5 g/sec with a coefficient of variation ([s/mean] x 100) of 9.7 %.

The quality of the meteorological data, particularly wind direction, can be critical. On one occasion, tracer gas was released while the measurement contractor indicated that the meteorological conditions were acceptable. As previously discussed, the wind direction must be such that the entire plume is captured within the IR beam; however, during this release of audit tracer, the FTIR analysis did not indicate any audit tracer gas. Further investigation showed that the wind direction sensor had been installed with a bias of 25 degrees. This bias was great enough to cause the audit tracer plume to miss the IR beam entirely, even though the SF_6 tracer plume was being captured completely. Emissions from portions of the lagoon near this audit tracer release point were undoubtedly also being lost.

The auditing reference for a true north was determined using solar noon. Another reference to a true direction was obtained from a National Oceanic and Atmospheric Administration (NOAA) weather station near the field site. The NOAA wind direction data confirmed that there was a significant bias in the wind direction data. The wind direction sensor alignment was corrected during the audit.

DISCUSSION

Placement of the reference tracer release point and of the IR beam is important in minimizing bias in the total measurement. The audit tracer data in the table above show excellent agreement when the audit tracer gas is released near the SF_6 tracer (*CTR* location); however, the upwind and downwind release points are biased low and high, respectively. This can introduce a significant bias in the overall estimate of emissions from the facility. A crude estimate of how much this bias would affect the emission rate for the entire facility was calculated based on a simple weighted average using the upwind (*SE & SW*), center (*CTR*), and downwind (*NE & NW*) results. This is shown in equation (2).

$$ER_{AVG} = \frac{0.32+0.19+2(0.49)+8.8+1.5}{6} = 1.97 \qquad (2)$$

This represents a total bias approaching 300%.

The effect of distance (between the tracer source and the IR beam) is to cause the portions of the lagoon nearest the IR beam to be greatly overrepresented in the calculated emission rate for the source. This distance effect would also cause the portions of the lagoon farthest from the IR beam to be underrepresented, but this is a much smaller effect, and may be within experimental error. Figure 2 provides a graphical representation of the calculated emission rates versus distance from the IR beam. Moving the beam downwind helps to linearize the distance effect, which would reduce the distance-dependent bias seen here.

There is also a major effect when meteorological sensors are not properly installed and oriented. Accurate determination of wind speed and direction is critical in the calculation of accurate emission rates. These meteorological measurements (speed and direction) should be assured with the same level of certainty as is given to the FTIR measurements. In particular, missing portions of the source or tracer gas emissions due to improper orientation can introduce bias and degrade precision.

CONCLUSION

FTIR data quality can be improved by more appropriate placement of the IR beam. Based on audit tracer results, moving the IR beam farther downwind would have produced a marked reduction in bias for this site. Increased downwind distance would also provide a better mixed plume, which would reduce the variability in concentration. The IR beam should also be long enough to accommodate normal wind shifts. Meteorological sensors should be carefully aligned and referenced to the orientation of the source. Finally, spreading the tracer gas release points over more of the lagoon area should also improve the resultant data quality. However, only a site-specific check with a second tracer that evaluates plume capture throughout the area source can verify that the siting is acceptable.

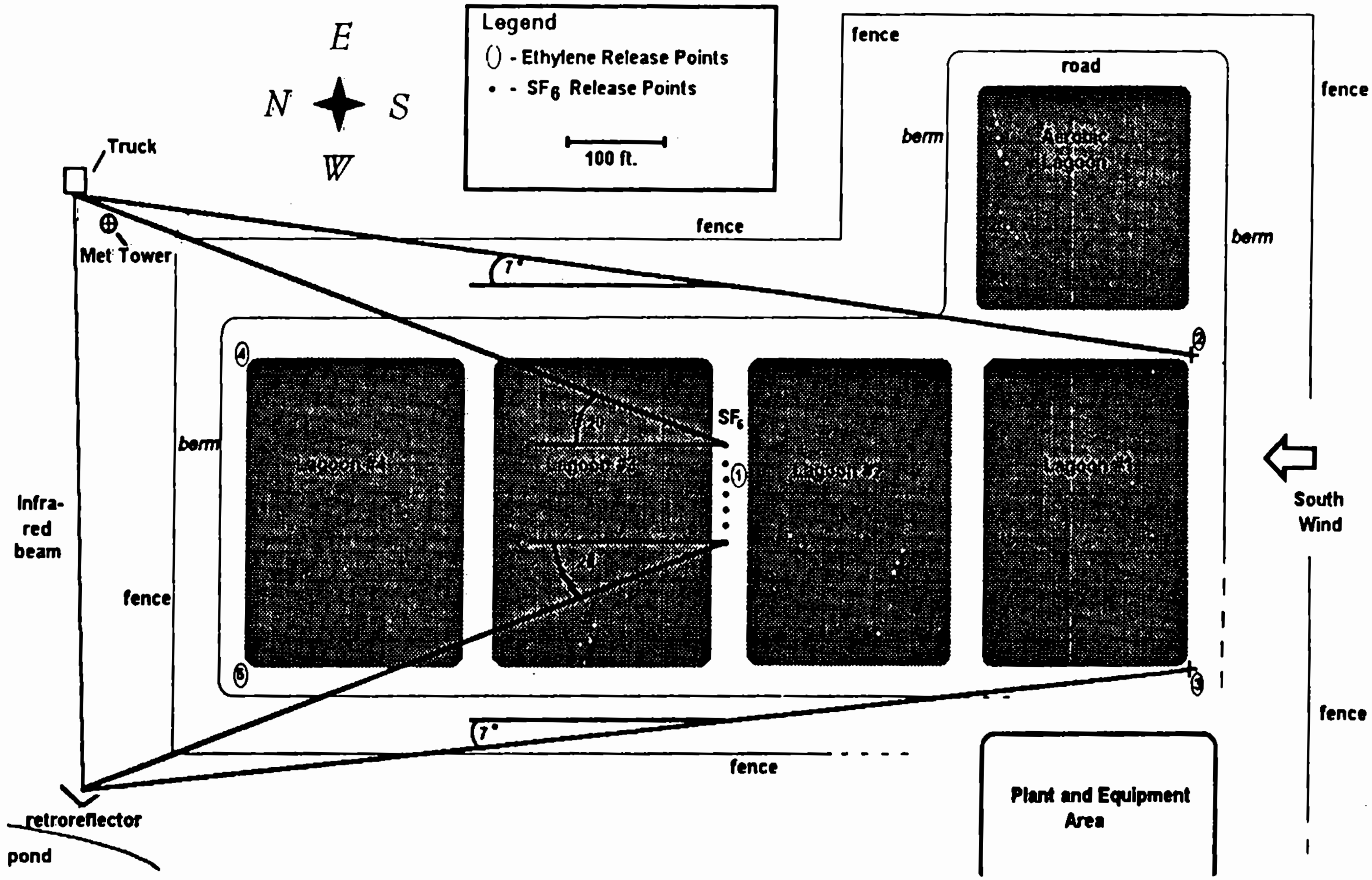

Figure 1. An overview of the waste water treatment facility and location of the IR beam.

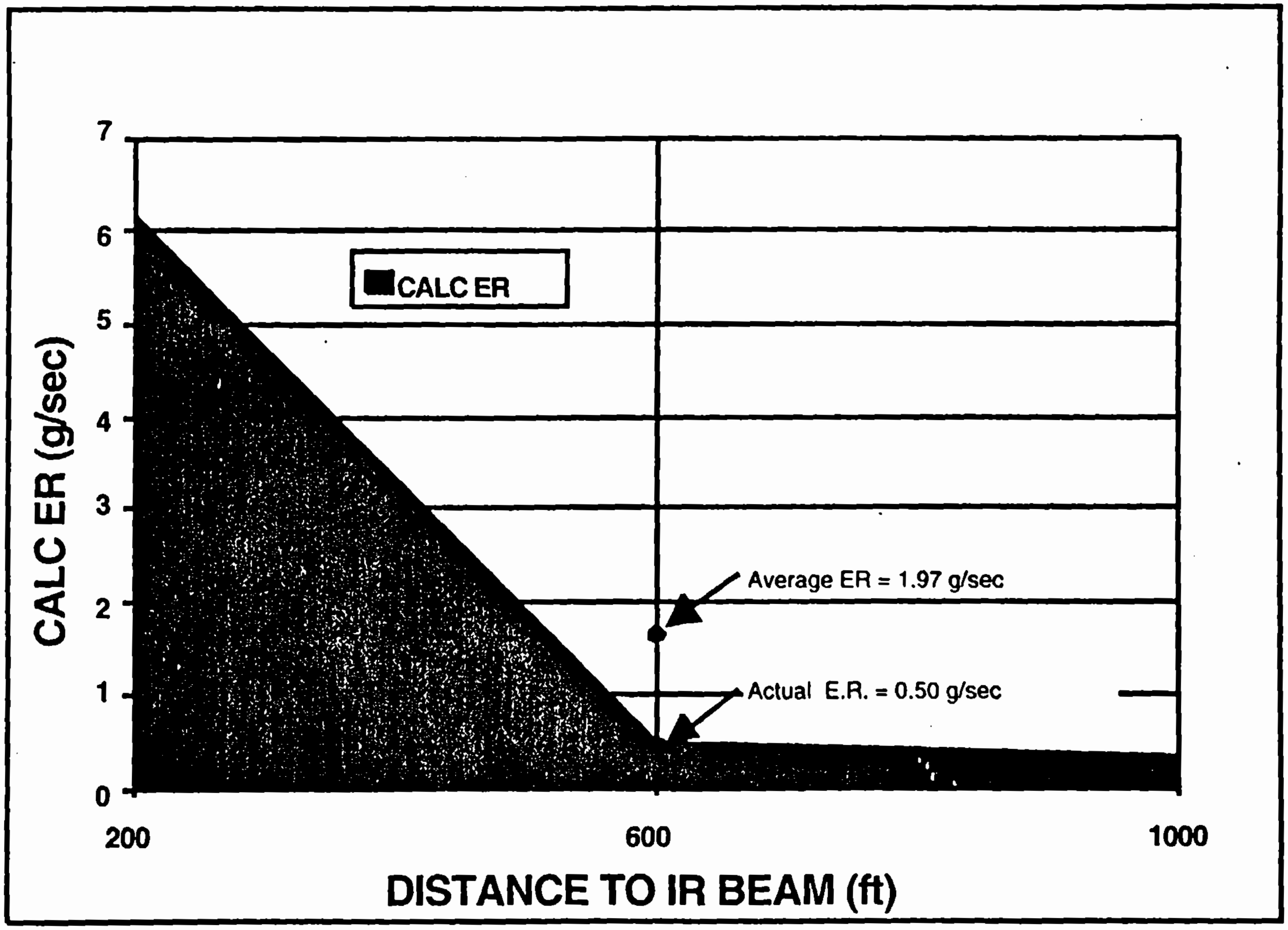

Figure 2. Graphical representation of calculated audit tracer emission rates versus distance from the IR beam.

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16. ABSTRACT The paper discusses three quality-related issues, found to be critical in calculating fugitive emissions: (1) length and location of the optical path relative to the source; (2) placement of the tracer gas release point; and (3) meteorological measurements. Open-path remote sensing techniques, such as Fourier transform infrared (FTIR) spectrometry, offer a powerful approach for determining emission rates from line and area pollution sources. Typically, a photon beam downwind of the source intersects the pollutant plume, and a characteristic such as optical absorption is measured. The path-integrated concentration is calculated from this measurement. The emission rate can then be estimated using a tracer gas reference or by dispersion modeling. Open-path monitoring has important advantages over conventional methods for measuring fugitive emissions. However, a different set of design and quality assurance considerations must be addressed in developing the measurement and data analysis protocols. Failure to consider the method's unique characteristics can impair the accuracy and precision of the results obtained from the calculation of fugitive emissions.

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Estimating		Stationary Sources	14G
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Emission		Fugitive Emissions	
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