United States
Environmental Protection
Agency

Air and Energy Engineering
Research Laboratory
Research Triangle Park, NC 27711

Research and Development

EPA/600/SR-94/166 November 1994

EPA

Project Summary

Estimate of Methane Emissions from U.S. Landfills

Michiel R. J. Doorn, Leonard A. Stefanski, and Morton A. Barlaz

Methane (CH_4) flow rates from landfills with landfill gas (LFG) recovery systems can be used as surrogates for CH_4 generation and successively for CH_4 emissions. The full report describes the development of a statistical regression model used for estimating CH_4 emissions, which relates LFG flow rates to waste-in-place data from 105 landfills with LFG recovery projects. The model has three linear segments, each of which applies to a distinct landfill size class. Assumptions were required to account for the recovery efficiency of LFG projects and for the probable oxidation of CH_4 in the top soil cover of the landfill.

National CH_4 emissions may be obtained by applying the regression model to municipal-waste-in-place data for U.S. landfills collected in 1986 by EPA's Office of Solid Waste (OSW). This value is adjusted for CH_4 emissions from industrial landfills and CH_4 that is currently recovered or flared. For 1986, CH_4 emissions from U.S. landfills were estimated at 11 tg (10^{12} g)/yr with lower- and upper-bound values of 7 and 15 tg/yr, respectively. For 1992, estimates were between 9 and 18 tg/yr. The solid waste disposal rate was estimated at 248 tg/yr.

The full report details uncertainties that limit the quality of the above estimates. Uncertainty arises from the difficulty in performing quality assurance on the waste-in-place data from a facility survey conducted by EPA/OSW. The report concludes with a discussion of trends that will affect future LFG emissions, as well as LFG utilization. Upcoming regulation for controlling air emissions from landfills is expected to be final by the fall of 1994 and to result in a reduction of 5-7 tg/yr of CH_4.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

CH_4 is a greenhouse gas of particular concern as its direct and indirect effects are estimated to be 20 times greater than that of an equivalent mass of carbon dioxide. Landfills are known to be a significant source of CH_4, with global emissions estimated between 20 and 70 tg/yr. However, the existing estimates on emissions from this source category were based on limited data using coarse assumptions. In an effort to improve estimates of global CH_4 emissions from landfills, the EPA's Air and Energy Engineering Research Laboratory began a research program aimed at identifying key variables that affect CH_4 generation and at developing an empirical model.

Landfills with gas recovery systems, where LFG is collected and measured by personnel on site, offer a unique opportunity for studying CH_4 emissions. LFG recovery rates can be used to estimate CH_4 generation which in turn can be related to CH_4 emissions. After the completion of a pilot study, a large-scale program was started where 21 landfills with LFG recovery systems were surveyed. The objective of this large-scale program was to develop a statistical model of annual landfill

CH_4 emissions as a function of climate, refuse mass and age, and other possible parameters, as well as obtaining an emission factor that could be used to estimate global CH_4 emissions from landfills. The report concluded that the mass of waste in place showed a significant correlation with CH_4 generation.

Because a large amount of the variability remained unexplained in the large-scale field study, it was decided to refine the correlation between LFG flow and waste mass. A larger LFG recovery data base was constructed, which included data from most U.S. LFG recovery projects. With the expanded and verified dataset containing data on 105 U.S. LFG recovery plants, a regression function was generated. This regression model, with three linear segments, is described in the report. In an appendix a simpler linear model is detailed, which is in fact an emission factor. It is suitable for use when only total-waste-in-place data are available, which is the case for most countries.

Regression Model

The LFG recovery data base was subjected to statistical regression analysis. The objective was to let statistical criteria dictate the shape and position of the regression curve with the constraint that the curve needed to start in the origin. A regression model with three different linear segments was the result, where each segment applies to a distinct landfill size class.

The size classes and equations for the three segments of the curve are:

I	$x < 1.128$	$y = 19.822\ x$
II	$1.128 \leq x < 4.082$	$y = 1.652\ x + 20.495$
III	$x \geq 4.082$	$y = 9.195\ x - 10.294$

where:

x = welded waste, tg and
y = LFG flow rate, m^3/min.

Welled waste is defined as the quantity of waste from which LFG is extracted through the recovery wells. In order to convert y in cubic meters per minute to the actual mass flow of CH_4 released to the environment in grams per minute, a factor needs to be introduced. This factor adjusts for the efficiency of the gas recovery system and for the percentage of CH_4 that is oxidized on its way out of the landfill. Recovery efficiency is estimated at 75%, and the oxidation is assumed to be 10%. The factor also adjusts for the amount of CH_4 in LFG, which is approximately 50%.

Estimate of Total Waste in Place

In 1986, OSW conducted a survey in which detailed information on 1,175 U.S. landfill facilities was compiled in a data base (EPA/OSW-Westat Database). This population was designed to be a stratified random sample of all U.S. landfills; therefore, its data could be extrapolated by means of scaling factors, to obtain total waste in place for the U.S. This data base contains data that make it possible to estimate waste in place by two different methods that are described and compared in the full report. The total amount of waste landfilled in the U.S. up to and including 1986 was estimated at 4.7×10^{15} g (5.2×10^9 tons).

Estimate of U.S. Landfill Methane Emissions

Application of the regression model to the waste mass data from the EPA/OSW-Westat Database and multiplication of the results with the conversion factor yield national CH_4 emissions from landfills. This estimate is then adjusted for the amount of CH_4 currently being recovered or flared. In 1992, 1.2 tg of landfill CH_4 was recovered and approximately 0.5 tg/yr of CH_4 was flared. It is estimated that an additional 15 tg of industrial waste is landfilled annually in the U.S. For 1986 CH_4 emissions from U.S. landfills were estimated at 11 tg/yr with lower- and upper-bound values of 7 and 15 tg/yr, respectively. Methane emissions from U.S. landfills in 1992 were estimated at 13 tg/yr with lower- and upper-bound values of 9 and 18 tg/yr.

Uncertainties and Future Trends

The full report details uncertainties that limit the quality of the emissions estimates. The main uncertainty arises from the inability to quality assure the waste-in-place data from the EPA/OSW-Westat Database. There are several indications that, since its publication, the data base has been subject to alterations: the scaling factors seem too high, waste-in-place data do not match up, and a density conversion has taken place. No documentation has been retrieved for any of these issues. The possible uncertainties are inflated by the update from 1986 to 1992. Other uncertainties arise from the fact that only few data are available for CH_4 generation at small landfills, because LFG recovery plants can usually be found at larger landfills.

Due to legislative and economic pressure, there will be a tendency toward larger and fewer landfills. Landfill gas recovery projects become more feasible as the landfill size increases, which should lead to a reduction in CH_4 emissions. As a result of source reduction, increased recycling, composting, and combustion, the yearly amount of landfilled waste will continue to decrease, which will also lead to a reduction in annual CH_4 emissions from landfills. The influence of changes in waste management will likely be overshadowed by the effect of the Clean Air Act rule as it is implemented over the next several years. This rule, requiring a gas collection system and add-on control device at affected landfills, is expected to result in the control of 500 to 700 sites, reducing CH_4 emissions by 5-7 tg/yr.

Michiel R. J. Doorn is with E. H. Pechan and Associates, Inc., Durham, NC 27707 and Leonard A. Stefanski and Morton A. Barlaz are with North Carolina State University, Raleigh, NC 27695.
***Susan A. Thorneloe** is the EPA Project Officer (see below).*
The complete report, entitled "Estimate of Methane Emissions from U.S. Landfills," (Order No. PB94-213 519; Cost: $19.50, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:
Air and Energy Engineering Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

United States
Environmental Protection Agency
Center for Environmental Research Information
Cincinnati, OH 45268

Official Business
Penalty for Private Use $300

EPA/600/SR-94/166