United States
Environmental Protection
Agency

Municipal Environmental Research
Laboratory
Cincinnati OH 45268

Research and Development

EPA-600/S2-84-141 Sept. 1984

EPA

Project Summary

Landfill Gas Production from Large Landfill Simulators

Larry W. Jones, Robert J. Larson, and Philip G. Malone

A study was conducted to investigate gas production rates and composition in municipal solid waste (MSW). Improved monitoring methods were used to corroborate and add to previous studies. A completely automated gas-monitoring system was used on four sanitary landfill simulators (lysimeters or test cells) of two different sizes.

Gas was produced in four phases: an aerobic phase, a nonmethanogenic anaerobic phase, an unstable methanogenic phase, and a stable methanogenic phase. The last stage was just being reached as the experiment was terminated.

The automated gas-measuring system and the gas-chromatograph-based, gas-analysis system used in the study both functioned satisfactorily. Gas samples were collected in an all-metal collection system, as plastic and glass vessels proved unsatisfactory.

The two sizes of test cells produced very similar volumes and compositions of total gas, but the small cells produced more methane and less hydrogen than the large cells. Relatively high, consistent levels of nitrogen were found in the gas from this study. This factor could pose serious problems regarding the use of this gas for energy.

The study demonstrated that the conditions present in the average MSW landfill are not ideal for maximum production of methane. Further studies are needed on the effects of environmental and nutritional factors in methane production.

This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, 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

Many investigators have reported the production of combustible gas from municipal solid wastes (MSW) placed in anaerobic environments such as landfills. But to exploit MSW as a possible fuel source, gas produced during its decomposition must be accurately analyzed and measured. This study uses improved monitoring methods to corroborate and add to previous investigations of MSW gas production rates and composition. The study also examines problems related to scaling of large laboratory simulation tanks. Two sizes of test cells were included to allow broad comparisons of the data obtained here with those of other studies. The project uses a completely automated gas monitoring system on four sanitary landfill simulators (lysimeters or test cells).

Methods and Materials

Test Cells

All gases were collected from four (two each of two sizes) carefully sealed MSW test cells. The cells were cylindrical steel (7.25-mm rolled plate) tanks. Each of the two smaller test cells had an inside diameter (ID) of 0.91 m and was 1.83 m high; each of the two larger cells had an ID of 1.83 m and was 3.66 m high (see Figure 1). All interior surfaces were coated with coal-tar epoxy to protect the walls from corrosion and the contents from contamination. Cells were loaded with a 30.5-cm layer of clayey-sandy soil, a 3-

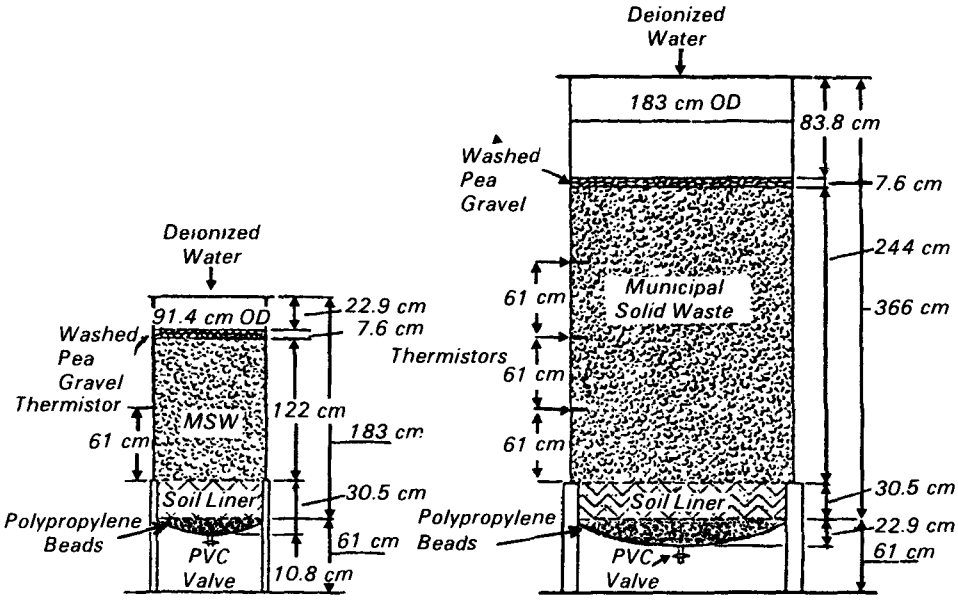

Figure 1. Schematic diagram of the municipal solid waste test cells.

cm layer of polypropylene beads (6.25-mm diameter), a layer of MSW (0.79 m^3 for the small cells and 6.42 m^3 for the large cells) from noncommercial collection routes in Warren County, Mississippi, and a 7.6-cm layer of washed pea gravel to help disperse the leaching fluid over the surface. A perforated diffusion pan was bolted to the inside of the test cell top as an additional aid, and a headspace (23 cm for the small cells and 84 cm for the large cells) was left below the test cell top plate. After the test cells were loaded and all monitoring devices were tested, the cells were sealed by welding the steel lids to the tops and pumping metal sealant into a machined groove on the undersides of the lids.

The test cell profiles were designed and constructed to simulate 1- and 2-m-thick cores of MSW taken from a municipal landfill. The test cells resembled medium-density cells in a sanitary landfill containing unprocessed wastes in the humid eastern United States.

Gas-Flow Measuring and Sampling Systems

The gas-flow measuring and sampling systems consisted of gas probes in each tank that collected the gas produced by the decaying waste, a gas-flow measuring and logging device, and a system that allowed the extraction of an uncontaminated gas sample for analysis.

Three gas probes were installed in each test cell. Each consisted of a perforated 0.6-cm copper tube coated inside and out with coal-tar epoxy to prevent corrosion by leachate. The copper tubing was fitted into a perforated polyvinyl chloride pipe to protect the tubing during waste compaction.

The gas-flow measuring system operates using a pressure-controlled flow. Components of the system include a differential pressure switch/gauge, three solenoid valves (normally closed), one linear mass gas flowmeter, one controller, seven shut-off valves, and one pressure gauge. A data logger was used to record gas production data from all four test cells.

Two sampling methods were tested during the first 18 days of test cell operation—one using flexible plastic bags and the other using stainless steel cylinders. The gas-bag system had to be abandoned because of oxygen diffusion into the bags. The system with stainless steel cylinders was used through the remainder of the experiment; it used grab samples collected from the test cells in glass gas bulbs through the gas-measuring system with the same pumping procedure used for the gas bags. Shortly after the change to grab samples, the O-rings on the gas bulbs began to leak, requiring the use of an all-metal system using a compressor and steel storage tank. After this all-metal system was installed, the oxygen levels were at or below detection limits.

Gas samples were analyzed on a Perkin-Elmer Sigma 3* gas chromatograph (GC) for oxygen, hydrogen, nitrogen, carbon dioxide, methane, and water vapor.

Data Reduction and Presentation

The raw data tapes from the data logger were read by a Martek Model 421-DRS magnetic tape reader and printed on a paper tape printer. Another magnetic tape reader transferred the data to a Hewlett-Packard Model 9830 computer through a Martex Model 421-12-DRS computer interfacing model. The data were then verified, reorganized, and stored in raw form on magnetic tapes in an array that allowed easy access and manipulation by the computer. The raw data were reduced by engineering units and corrected for the nonlinear output from the thermistors and barometric pressure sensors and for variations in gas composition. Programs have been developed to present the final data in any of several forms.

Results

The relative amounts and kinds of gases found in this study correspond with those reported for the theoretical stages of bacterial succession in common anaerobic digestors: (1) an aerobic phase, (2) a nonmethanogenic anaerobic phase, (3) an unstable methanogenic phase, and (4) a stable methanogenic phase. Gases produced in the last phase are the most desirable since they are usually 45% to 60% methane, with the balance being easily removed carbon dioxide.

The aerobic or first phase consisted of the rapid uptake of any residual oxygen in the MSW and the release of nearly equal amounts of carbon dioxide. This phase apparently took place before the first gas sampling, 24 to 48 hours after the cells were sealed. Only very low levels of oxygen were found in these first samples. This result could be due to the high initial temperature of the waste, which would result in high metabolic rates for the microbiological flora.

The anaerobic second phase was indicated by the production of large volumes of carbon dioxide. This phase was also well under way in the first 2 or 3 days after cell sealing. The total gas output of the cells (mainly carbon dioxide and

*Mention of trade names or commercial products does not constitute endorsement or recommendation for use

nitrogen) decreased dramatically over the next 100 to 150 days as the MSW approached water saturation and leachate production. Hydrogen production was noted in all of the test cells 60 to 90 days before methane was detected in any of them.

The third phase (unstable methanogenic) began for three of the four test cells at about the time that leachate began to be produced, between days 250 and 300. Methane evolved slowly and somewhat variably over the remainder of the experiment, with the gas output attaining 10% to 25% methane only after nearly 4 years of fermentation.

The fourth phase (stable methane production), with its constant 40% to 60% methane concentrations, was never reached by any of the cells over the 1500 days of the study. But all of the cells were increasing in methane production when the experiment was terminated. In only one of the small cells did the percentage of methane in the released gas increase continuously, reaching 26% by the end of the experiment and still increasing.

The absence of a stable methane production phase may have been caused by less-than-optimum conditions in the leachate such as low nitrogen-to-carbon ratios and low total volatile acids as substrates for the methanogenic bacteria. Other factors may have been the lower-than-optimum temperatures in the uninsulated test cells, high levels of toxic metals or organics, or the acidic pH's of the leachates. Stable methane production is not uncommon after only a few weeks under ideal circumstances; but development times of 100 to 300 days are more common, and longer times are not unusual.

The total volume of gas produced varied only about 12% between the small and large cells (17.75 and 20.1 ml/kg dry MSW per day, respectively). Compositions of the total gases evolved were also quite consistent for the major gases from all test cells (70.5% and 69.6% for carbon dioxide and 19% and 21% for nitrogen in the small and large cells, respectively). These values represent the first 630 days of the experiment. During the same period, fermentative activity in the test cells was quite consistent. The same consistency is shown for the first 100 days when about half the total gas was produced.

The relatively high, consistent levels of nitrogen found in the gas from this study could pose serious problems regarding its use for energy. These levels could have resulted from denitrification, or they could have been due to contaminating air drawn into the test cell. Further study of these causes and careful monitoring of nitrogen levels is needed in future studies of methane production.

The amount of flammable gases produced varied considerably within both sizes of test cells. Hydrogen was the only gas that had consistent variations between the small and large test cells, and this result may be accounted for by chance. The smaller cells consistently produced much less hydrogen than the larger cells over the first 630 days of the experiment, possibly because of the larger methane production in the smaller cells.

Conclusions

The use of an automated, gas-measuring system effectively monitored the volume of gases released from four landfill simulation test cells. Results show that conditions present in the average MSW may not be ideal for maximum methane production, but that very appreciable amounts of methane (and carbon dioxide) can be expected from the average landfill over extended periods. Further studies of the effects of environmental and nutritional factors on the time required to develop stable methanogenic conditions and bacterial populations are needed so that conditions in the landfill can be modified to maximize or minimize methane production, depending on the use to be made of the site.

The full report was submitted in fulfillment of Interagency Agreement No. EPA-IAG-D4-0569 by the USAE Waterways Experiment Station under the sponsorship of the U.S. Environmental Protection Agency.

Larry W. Jones, Robert J. Larson, and Philip G. Malone are with USAE Waterways Experiment Station, Vicksburg, MS 39180.
***Robert E. Landreth** is the EPA Project Officer (see below).*
The complete report, entitled "Landfill Gas Production from Large Landfill Simulators," (Order No. PB 84-235 779; Cost: $13.00, 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:
Municipal Environmental Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, OH 45268

☆ U S GOVERNMENT PRINTING OFFICE, 1984 — 759-015/7822

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati OH 45268

BULK RATE
POSTAGE & FEES P
EPA
PERMIT No. G-35

Official Business
Penalty for Private Use $300