United States
Environmental Protection
Agency

Hazardous Waste Engineering
Research Laboratory
Cincinnati OH 45268

Research and Development

EPA/600/S2-86/110 Apr. 1988

EPA

Project Summary

Evaluation of Municipal Solid Waste Landfill Cover Designs

John R. Dwyer, John C. Walton,
Wendy E. Greenberg, and Ronald Clark

The HELP (Hydrologic Evaluation of Landfill Performance) Model was used to evaluate the hydrologic behavior of a series of one-, two-, and three-layer cover designs for municipal solid waste landfills. The specific landfill cover designs studied were chosen to isolate the effects of features such as surface vegetation, thickness, soil type and hydraulic conductivity of the layers on the average annual runoff, cover percolation, evapotranspiration, and lateral drainage. The results of the evaluations are presented in numerous bar charts to supplement the tables and schematics.

Soil hydraulic conductivity was one of the most important design features in controlling cover percolation for all covers tested.

Minimal cover percolation and runoff were the two main criteria used to select the four best cover designs, which are described under Results and Discussion. The full report also includes a brief discussion of four other aspects of landfill cover design: animal and vector control, subsidence, gas control, and cost.

This Project Summary was developed by EPA's Hazardous Waste Engineering 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

A primary concern associated with municipal solid waste landfill construction is ground-water pollution caused by precipitation becoming contaminated as it moves through the wastes in the landfill and percolates into the ground-water flow system. An important objective of landfill design is to minimize ground-water pollution by controlling the water percolating in and subsequently out into the ground water. To help landfill designers meet this objective, the U.S. Environmental Protection Agency developed the HELP Model, a computer model that simulates water movement in and out of a landfill under a variety of landfill cover designs and climatic conditions. The Model uses a water balance approach.

A typical landfill can be subdivided into three basic components: the landfill cover or cap, the waste layer, and the liner. The landfill cover provides the first line of protection for the landfill. A well-designed cover prevents water from coming into contact with the waste layer, and minimizes the risk of subsequent ground-water contamination. The waste layer contains the landfill refuse and the liner is the bottom barrier which is designed to protect the ground water from contamination.

Procedure

The HELP Model simulates a multi-layered landfill and provides a variety of options for selecting the number and type of layers in the landfill, the hydrologic properties of the layers, surface vegetation, and other features of the design. It then simulates water movement through the landfill based on temperature and precipitation data from one of several dozen U.S. cities. The HELP Model calculates the components of the water balance for a specified landfill design, including, runoff, evapotranspiration, lateral drainage and percolation. These parameters can be average annual values, monthly values, or daily values, depending on the HELP Model option selected. The results of the model provide the user with information on the effectiveness of landfill design components for controlling water movement through the landfill.

Results and Discussion

Minimal cover percolation and runoff were the two main criteria used in selecting the best cover designs. Four cover designs met these objectives and are described below.

(1) The one -layer covers showed reduced percolation as the cover soil ranged from coarse-textured (sandy) soils to fine-textured (clayey) soils. Percolation for one layer covers using a clayloam soil was measured as less than 5 inches in Denver, San Francisco, Corpus Christi, and Milwaukee, where the average annual precipitation is less than 33 inches.

(2) Two-layer covers with a 6-inch gravel layer over a clay barrier, percolated less than 1.7 inches for all 10 cities tested. Runoff was relatively high ranging from 1.6 to 24 inches for the 10 cities.

(3) Percolation was slightly reduced for two-layer covers consisting of a topsoil layer over a clay barrier as the soil texture of the topsoil layer went from coarse to fine. Cover percolation increased by 0.6 to 0.8 inch when the thickness of the clay barrier layer was reduced from 24 to 12 inches. Cover percolation was reduced by an approximately factor of 10 when the hydraulic conductivity of the barrier layer reduced by a factor of 10. The HELP Model results indicate that these covers experienced saturation of the topsoil layer during the 10 to 20 year periods recorded for the 10 cities tested. This saturation could be harmful to vegetation and could result in excessive surface runoff, depending on the frequency and persistence of saturation under a particular climatic regime. Further investigation is necessary to determine the suitability of these cover types for a given climate.

(4) Three-layer covers consisting of a topsoil layer, a drainage layer, and a clay barrier reduced percolation by 0.25 to 0.55 inch when clay loam instead of sandy loam was used in the topsoil layer. Reducing the hydraulic conductivity of the drainage layer by a factor of 8.4 resulted in a reduction in cover percolation ranging from 0.5 to 0.9 inch for the 10 cities. Results for Lexington, Kentucky indicated that cover percolation was reduced by 3 to 5 percent for every 1 percent increase in the slope of the drainage layer and was reduced by 3 to 9 percent for every 25-foot decrease in drainage spacing, as the spacing ranged from 200 to 25 feet. Reducing the hydraulic conductivity of the barrier layer by a factor of 10 significantly reduces cover percolation. The amount of the reduction depends on the initial value of the hydraulic conductivity and the precipitation at the site.

Conclusions and Recommendations

The findings from this study provide useful guidelines for designing a cover for a specific landfill site in a particular climatic regime. However, the results presented in this report describing the effects of various design parameters on the hydrologic performance of landfill covers are predictions based on the HELP Model and should not be interpreted as absolute predictions of landfill behavior. The results, which compare the hydrologic performance of various types of one-, two-, and three- layer covers, are intended to help determine the relative importance of various design parameters in terms of their effect on hydrologic performance for a range of climates.

Because this report analyzes the hydrologic behavior of landfill cover designs solely in terms of average annual values, the performance of a cover design during a storm, although important, was beyond the scope of this analysis. Although the full report deals primarily with annual averages, the HELP Model can be used to analyze the daily water balance of a cover design, employing user-supplied daily precipitation data.

The hydraulic conductivity of one-layer cover designs, as determined by soil type and degree of compaction, is the most important design feature in controlling cover percolation. For two- and three-layer covers containing a barrier layer, the hydraulic conductivity of the barrier is the single most important parameter in controlling cover percolation. Cover percolation can be specified by adjusting the hydraulic conductivity of the barrier layer for most of the two- and three-layer cover designs examined in this study.

Three-layer covers that include a drainage layer generally result in lower cover percolation than one- or two-layer covers. Results of this study also show that the hydrologic behavior of the same landfill cover design can vary significantly in different climates.

In designing a landfill cover, performance criteria should first be established. These include the objectives of the design, namely the maximum amounts of cover percolation and runoff, and the acceptable amount and frequency of vertical percolation layer saturation. These objectives are based on such factors as: the type of waste to be stored in the landfill; the type of liner beneath the waste layer; geologic conditions in the vicinity; the storm magnitude that the cover is intended to withstand; the local climatic regime; the potential threat of groundwater contamination; proximity to aquifers, residential areas, or wildlife habitat; and budget constraints.

Animal and vector control, subsidence, gas control, and cost are four other factors considered in landfill cover design. Animals burrowing at landfills can be controlled by using a cover of dry, loose gravel and sand to discourage tunneling. Birds and insects can be controlled by installing a thick, compacted, well-graded surface layer.

Techniques for controlling subsidence of landfill covers are still being developed, but can be divided into two categories: (1) those that control subsidence in the waste layer and (2) those designed so the cover layer features minimize the effects of subsidence. Techniques used in the first method increase the ratio of daily soil cover to waste, and compaction. An example of the second is to create a stable foundation or at least a 24-inch buffer layer of compacted sand or gravel between the base of the cover and the waste layer.

Control of methane gas and volatile toxic vapors at landfill sites is an important consideration. Methane control techniques are designed to limit methane production and to control lateral subsurface migration by venting the gas to the atmosphere. With volatile toxicants, both lateral migration and atmospheric emissions must be controlled. Some of the techniques for gas control are gas drainage layers with vents, vertical pipe vents, trench vents, and induced gas extraction systems. These techniques are discussed briefly in the report. References describing these techniques in more detail are listed in the report bibliography.

The major expense in landfill cover construction is the material and installation costs for topsoil, sand, clay, and synthetic liners. The report also gives cost estimates for the four recommended cover types.

The full report was submitted in fulfillment of Contract No. 68-03-3248, Work Assignment No. 5 by Battelle Columbus Laboratories under the sponsorship of the U.S. Environmental Protection Agency.

John R. Dwyer, John C. Walton, and Wendy E. Greenberg are with Battelle Denver Operations, Denver, CO 80209; Ron Clark is with Battelle Columbus Laboratories, Columbus, OH 43201.

***Robert Landreth** is the EPA Project Officer (see below).*

The complete report, entitled "Evaluation of Municipal Solid Waste Landfill Cover Designs," (Order No. PB 88-171 327/AS; Cost: $19.95, 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:

Hazardous Waste Engineering Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, OH 45268

☆U.S. GOVERNMENT PRINTING OFFICE: 1988—550-289/62071

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati OH 45268

EPA/600/S2-86/110