Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 54(11) (2023) 879-882
DOI: 10.22060/ceej.2022.20944.7575

A strategy in developing standards for the liner of municipal solid waste landfills in Iran

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ABSTRACT: The difference in climatic conditions across the country and low investment capacity in waste management systems makes it unrealistic to establish the same prescribed design for the bottom liner of municipal solid waste landfills. In this paper, a semi-performance-based approach for the proper design of liners in these landfills has been proposed. This approach has been used in the development of technical evaluation guidelines and environmental criteria for municipal and hazardous waste landfills. Therefore, different climatic and hydrogeological conditions were considered. The rate of leachate infiltration into the leachate collection system in different climates corresponding to high, medium and low precipitation was calculated using the HELP model and considered as a representative parameter of climatic conditions. The rate of waste deposition, which indicates the size of the landfill, was introduced as the length of the landfill along the groundwater direction. Groundwater velocity, hydraulic conductivity and thickness of the aquitard were used as hydrogeological parameters. The resulting scenarios (324 scenarios) were defined in POLLUTE v7 and the chloride migration in five liner options were modeled. The results show that as the landfill is larger and the hydraulic conductivity of the aquitard is higher, the maximum contaminant concentration in the aquifer and the required time period to reach the maximum concentration will increase and decrease, respectively, by reducing the different layers of the liner system and decreasing groundwater velocity. Finally, the optimum liner for all climatic and hydrogeological conditions is proposed based on modeling results.

Review History:

Received: Jan. 02, 2022
Revised: Jul. 15, 2022
Accepted: Aug. 07, 2022
Available Online: Aug. 18, 2022

Keywords:

Performance based design
leachate
Contaminant transport
Landfill liner design
Soret coefficient

1- Introduction

Landfilling is the most widely used waste management method in low and middle-income countries including our country [1]. Landfill liner acts as a barrier and minimizes the effects of landfill pollutants on the surrounding environment [2]. Performance-based design and prescribed technical standards are two different approaches usually used in landfill liner design [3].

Here a semi-performance-based approach has been used to develop the national criteria for landfill liner design. This paper explains the research and methodology that led to these standards which are published in the guidelines of department of environment.

2- Methodology

Landfill leachate transport modeling usually consists of two steps: first, leachate generation and its leakage from liners and second, transport and migration of pollutants into an aquifer [4]. In the first step, design variables and their intervals were determined. For example, for climate as a variable, the average precipitation in each region was defined by considering the different climatic conditions in the country. All the design variables (climate, landfill size, groundwater seepage velocity, thickness and hydraulic conductivity of the aquitard) were classified according to the defined intervals and were used as model inputs. In second step, a list of different design scenarios for the landfill liner were defined. In this study, the maximum allowable head on the liner (30 cm) and the maximum concentration of leached pollutants in groundwater were considered as the performance criteria. Therefore, in the third stage, the designs that met the performance criteria were selected and suitable liners for each scenario were determined.

POLLUTE v7 is used to model contaminant transport beneath the landfill site. A review of leachate transport modeling shows that three computer models the LandSim, Pollute, and IWEM (Industrial Waste Evaluation Model) are the only computer models found to be specifically designed to simulate contaminant transport in groundwater [4]. Percolation through landfill cover was calculated for different climates using The Hydrologic Evaluation of Landfill Performance (HELP) computer program.

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3- Results and discussion

For each climate, 27 different scenarios considering four liner designs (L1 to L4 equivalent to natural clayey soil and leachate collection system (LCS), one layer (60 cm) of compacted clay liner (CCL), one layer of geomembrane, CCL (60 cm) and geomembrane, respectively). Also, two other options (L0 (no liner and LCS) and L5 (higher thickness (75 cm) of CCL and geomembrane) were controlled.

The top boundary condition (at the bottom of the landfill cell and the point of contact between the contaminant source with the bottom layer) is defined as the finite mass of contaminant. The bottom boundary condition (the point of contact between the vadose zone and the aquifer) is defined as fixed outflow velocity. In this boundary condition the base aquifer is modeled as a boundary condition (not a separate layer) and the concentration at the bottom of the model is the concentration at the top of the base aquifer [5].

Modeling results are shown in Figure 1. Landfill contamination increased with precipitation. In low-precipitation climate (0.088 m/a infiltration rate) the continuity condition is satisfied in almost all scenarios. However, the number of scenarios that do not meet the continuity condition increased as the infiltration rate increased. When the precipitation is high (0.408 m/a infiltration rate), the maximum concentration occurred with L1 and in the conditions where the hydraulic conductivity of the natural clayey soil is 10^{-8} m/s and small landfill. Also, the time to reach the maximum pollutant concentration in the aquifer is about 17 years. In moderate precipitation (0.195 m/a infiltration rate), such conditions occur with L1 in small landfill and when the hydraulic conductivity of the natural clayey soil is 10^{-6} m/s. In this case, the time of maximum concentration in the aquifer is about 22 years. However, when the precipitation is low, the maximum contaminant concentration in the aquifer occurred with L4 in the large landfill and when the hydraulic conductivity of the aquitard was 10^{-5} m/s. The time to reach the maximum concentration in the aquifer is about 138 years. In similar conditions (for large landfill and aquitard hydraulic conductivity of 10^{-5} m/s), the corresponding scenarios in moderate and high precipitation did not fulfill the continuity condition. Therefore, the adequacy of the liner was rejected without simulation. Obviously, all critical conditions were observed in very low groundwater velocity (18 m/a). Numerical results from previous studies show that for CCL, the COD concentration in breakthrough curve reached a maximum earlier than CCL and a geomembrane layer [6]. Du et al also reported that in the rate of leachate leakage from a natural clayey layer with a hydraulic conductivity of less than 10^{-9} m/s is about five to eight times higher than that of the composite liner [7].

In the next stage, the suitable liner is proposed for each condition based on modeling results. The country is divided into four regions based on the average annual precipitation and evaporation, humidity and the field capacity of deposited wastes. As the infiltration rate to the LCS is higher, the landfill is larger, the groundwater velocity is lower, and the hydraulic conductivity of the natural clayey soil is higher, a more complex liner system is needed.

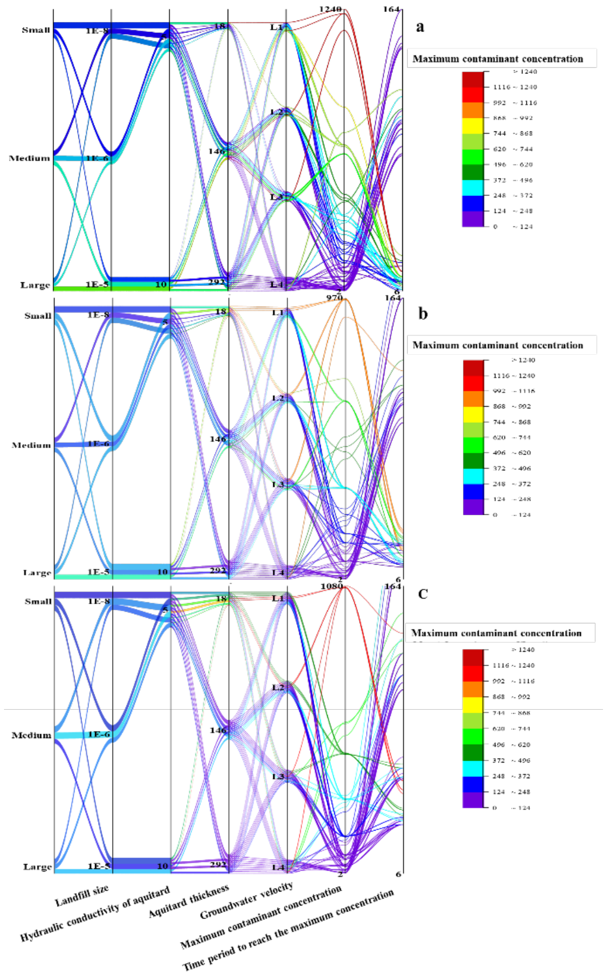

Fig. 1. The maximum contaminant concentration and times to reach the maximum concentration in aquifer in different modeling scenarios and leachate infiltration rate of a-0.408, b-0.195 and c-0.088 m/a.

4- Conclusions

The aim of this study was to propose national standards for the liner system in municipal solid waste landfills. Proposing similar design in all situations around the country is one approach that may be used for this purpose. Considering the climatic diversity and the differences in landfill size in small and large cities, such an approach can be very conservative, imposing excessive costs. In another approach, the performance of the barrier system can be used as the basis for decision-making in each situation. It is usually necessary to use a numerical or analytical model (if available) in this approach to make sure the design is adequate. However, considering the limitations (small landfills and remote residential areas), it is unrealistic to require modeling in all cases. Therefore, a semi-performance-based approach was taken. For this purpose, different scenarios are defined taking into account the amount of leachate infiltration into the LCS, the thickness and hydraulic conductivity of the natural clayey soil, the groundwater velocity and the size of the landfill and the liner performance was evaluated by 324 simulations.

The results showed that the larger landfill size and the higher hydraulic conductivity of aquitard, the maximum pollutant concentration in the aquifer will be higher with the change in the liner arrangement from L4 to L1 and the reduction of the groundwater velocity. These conditions are intensified by increasing the infiltration rate into the LCS. Times to reach the maximin contaminant concentration decreased as the leachate infiltration increased. The contaminant dispersion/mixing decreases as the groundwater velocity decreases. Therefore, the most critical scenarios usually happen in low velocities. It should be emphasized that proposed liner designs are valid within the framework of the assumptions and simplifications of this study.

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HOW TO CITE THIS ARTICLE

N. Jamialahmadi, M. Hashemi, M. Karimpour-Fard, A strategy in developing standards for the liner of municipal solid waste landfills in Iran, Amirkabir J. Civil Eng., 54(11) (2023) 879-882.

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