Predicting Lead (Pb) Contaminant Migration through Landfill Liner

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Abstract. Temanggung Landfill is equipped with a liner system that consists of gravel, geotextile, geomembrane, and compacted clay. However, there is still potential for contaminant mobilization through liners to the surrounding environment, especially the soil beneath the landfill. The purpose of this research is to simulate the movement of lead (Pb) in landfill, vertically at every depth. Contaminant migration from landfill across time can be predicted using POLLUTEv7 software, a one-dimensional model that can describe contaminant mobilization affected by dispersion, advection, diffusion, and retardation phenomena. Over a period of 15 years simulated by the model, the concentration of Pb increased continuously. The initial concentration of Pb above the liner was 0.56 mg/l. This level dropped to 0.35 mg/l after passing the liner in the first year, then increased to 0.4106 mg/l in the second year, and kept increasing up to 0.5071 mg/l in the 15th year.

1 Introduction

The characteristics of municipal solid waste leachate are influenced by the type of solid waste buried in landfill. Most of the solid waste in developing countries going to landfill is in the form of mixed and unsorted waste. Some hazardous waste are also dumped in landfills [1]. During the decomposition process of solid waste, leachate will be produced and flow to the bottom of the landfill [2]. Typically, a landfill is equipped with a semi-permeable liner that functions to prevent leachate escaping to surrounding soil [3]. However, a small amount of leachate still passes through the liner and migrate into the soil due to seepage or liner leakage [4].

Temanggung Landfill started operations in 2012, and was equipped with a liner system that consisted of gravel, geotextile, geomembrane, and compacted soil. That system functioned to stop leachate escaping from the landfill area. Temanggung Landfill mainly relied on the geomembrane layer as a leachate barrier. However, since the geomembrane does not endure pressure and accumulation of leachate containing heavy metals over a prolonged period, there is some possibility of it puncturing or cracking.

Leachate is generally toxic because it contains heavy metals and various other organic pollutants that can contaminate soil and ground water. Because of electronic waste, a

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predominant heavy metal in landfill leachate is lead (Pb) [5]. Thus, this study focuses on predicting Pb migration from landfill over a period of 15 years, using average Pb concentrations in some solid waste landfills. The purpose of this study is to predict lead (Pb) concentrations in the soil beneath the landfill using Pollutev7 software, a one and a half dimensional model to the advection-dispersion equation [6]. Some studies have previously used POLLUTEv7 software to effectively predict contaminant movement from landfill. This software has also been used in landfill research in other countries, such as China [7] and Canada [8].

2 Methods

Preliminary tests were conducted to measure Pb concentrations in leachate. The leachate sample was collected from the leachate treatment plant inlet. Pb concentrations in the inlet were assumed to represent the leachate concentration at the bottom of the landfill. Water samples were also taken from two monitoring wells surrounding the landfill. Other information such as soil characteristics of the Temanggung Landfill (permeability, porosity, dry density, and grain size), the types of soil layer, their location and layer thickness, were also collected.

All information was entered in the POLLUTEv7 software (Fig. 1). To get a reliable result, all parameters must be complete, including the thickness of each layer. The POLLUTEv7 software is user-friendly and developed from a one and a half dimensional model. The software also allows for some default values, in anticipation of incomplete data. However, the results are more reliable if all the parameters required by the software are measured from the field.

The information was then used as model inputs and processed using the POLLUTEv7 software (Figure 1). After running the model, the software provided a list of tables and graphs showing the calculated results, which can be the amount of contaminant concentration to time, the amount of contaminant concentration to depth, and the depth to time. There were some assumptions and limitations in the study. For example, it assumed that the ground water movement is in steady state condition, the soil types in the landfill are homogenous, and concentration of contaminants is constant.

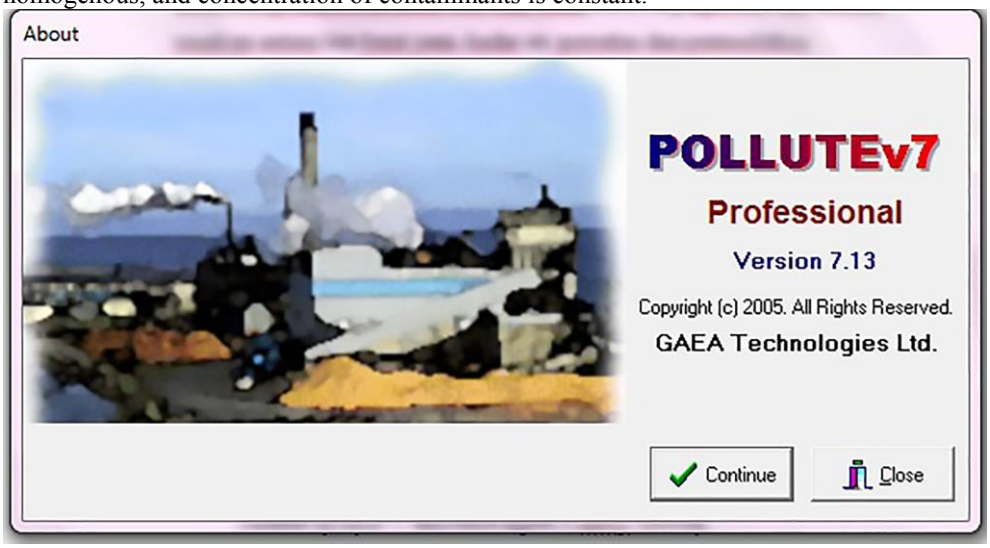

Fig. 1. A screenshot of the POLLUTEv7 Software

3 Results and Discussion

3.1 Properties of the Liner

Temanggung Landfill has been equipped with a leachate barrier that consists of various materials. A gravel layer with permeability of $1x10^{-1}$ m/s acts to drain leachate and protection for leachate collection pipe. The geotextile is laid underneath the gravel layer, and is followed by a geomembrane layer that has a very low permeability of $5x10^{-10}$ m/s. The geotextile functions to protect the geomembrane. Below the geomembrane, there is compacted soil layer and native soil 1 and 2. While the permeability value for compacted soil is quite low at $1.109x10^{-7}$ m/s, small amounts of leachate can still pass this layer. The properties of all layers are presented in Table 1.

Table 1. Initial Data

No	Landfill layer	Permeability (m/s)	Coef. Hydrodinamic Dispersion (D) (m^2/s)
1.	Gravel 3/5	1.00 e-01	51.43497152
2.	Geotextile	6.50 e-02	2.630784222
3.	Geomembrane	5.0 e-10	1.3491 4e-08
4.	Compacted Soil	1.109 e-07	4.67379 e-06
5.	Native Soil 1	3.2387 e- 06	0.000109061
6.	Native Soil 2	6.3834 e- 06	0.000122617

3.2 Findings

The initial Pb concentration above the liner was 0.56 mg/L. Once past the liner system, the concentration of Pb decreased to 0.395 mg/L, and continued to decrease to 0.358 mg/L at a depth of 7.1 m. However, due to accumulation, contaminant levels of Pb were predicted to increase year to year at each depth level, from year 1 to year 15. In the 1st year, the Pb concentration at the depth of 7.1 m was 0.358 mg/L. In the 2nd year, Pb concentration was predicted to increase to 0.4106 mg/L, and to keep increasing up to 0.5071 mg/L in the 15th year. The increase in concentration is caused by accumulation of Pb and the process of diffusion and dispersion in soils [9]. Annual increments of concentration varied; however, they became very small after the 8th year. Changes in Pb concentrations of Pb are depicted in Figure 2.

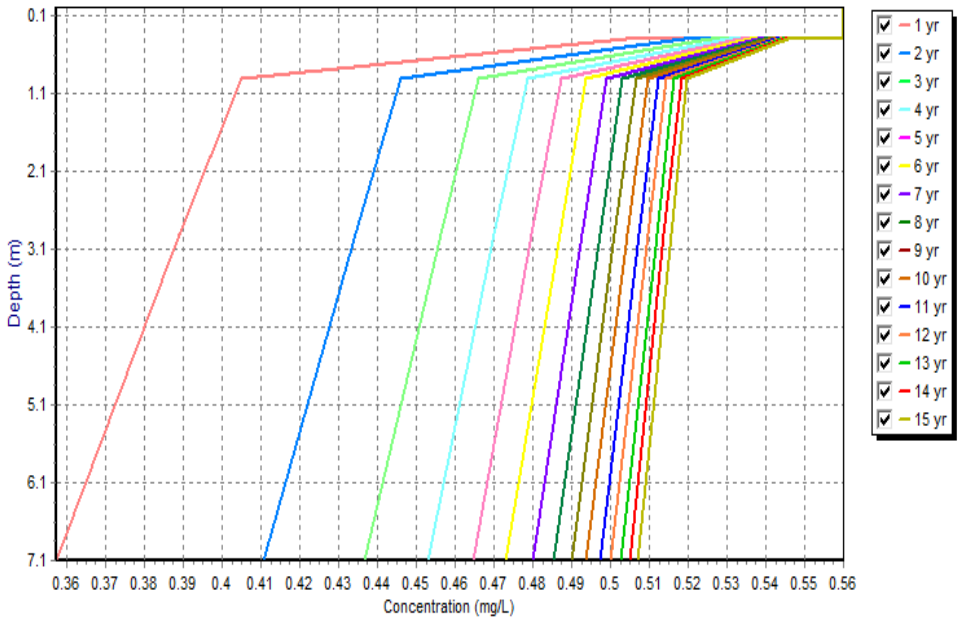

Fig 2. Predicted Pb Concentrations at Different Depths over a Period of 15 Years

Assuming that the Pb concentration in leachate remains constant, Pb concentration in the soil at 7.1 m depth will not reach 0.51 mg/L within 15 years. However, if there are any changes in Pb concentration in leachate, the current model will no longer hold and another simulation will need to be run.

Involving a model to predict the Pb concentration in the soil underneath a solid waste landfill over the year would become a real challenge for landfill's authorities. In order to avoid any misleading result, a careful consideration should be taken into account when performing the simulation. The Pb concentration in leachate should be monitored in regular basis, such as in every month or two months followed by simulating the model base on the concentration obtained during monitoring activities. Any potential change of other parameters that possibly altering the result should also be considered in the developed model. The result of the simulation then should be validated accordingly by performing some field samplings and re-adjusting the model once any escalating on the deviation of the result occurred.

4 Conclusion

Leachate containing Pb in the Temanggung Landfill can be simulated using a one and a half dimensional model using POLLUTEv7. The simulation is very useful for policymakers and the Temanggung Landfill authority who are interested in predicting Pb contamination. The concentration of Pb at the bottom of the landfill was found to be 0.56 mg/L. The Pb concentration was then predicted to decrease to 0.415 mg/L after passing the main leachate barrier, which is a geomembrane layer. The concentration of Pb in every soil layer was predicted to increase from year to year, because of Pb accumulation at every depth. However, a routine monitoring of Pb concentration in the leachate collection system should be conducted followed by model simulation to avoid any invalid results.

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