**UNIVERSITI TEKNOLOGI MARA**

# NOMOGRAPH MODELLING OF HYDRAULIC CONDUCTIVITY FOR LANDFILL SOIL LINER USING BOILER ASH-BASED GEOPOLYMER

**ATIQAH NAJWA ZAINUDDIN**

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# ABSTRACT

The study investigates a green technology geopolymer as an additive in enhancing the properties of landfill soil liner. Soil liners are used to contain waste in modern landfills. Essentially, the liner system isolates the landfill contents from the surrounding environment and protects the soil and groundwater from pollutants originating from the landfill. Liner requires low hydraulic conductivity ($1x10^{-9}$ m/s) and adequate shear strength. Laterites are of great interest because of their abundance, availability, and easy workability. Despite the source of laterite in construction, the soil type is hard, impenetrable, and has high permeability. Geopolymer can be considered the key factor that could enhance laterite's properties in the performance of hydraulic conductivity. Geopolymer paste consists of palm oil boiler ash mixed with an alkaline solution of sodium hydroxide and sodium silicate. Boiler ash is another industrial waste product from the combustion of coal. In this study, laterite mixed was mixed with different percentages of boiler ash-based geopolymer (GeoPOBA) to improve the properties of soil liner application. This research aims to determine the optimum percentage of geopolymer mixed with laterite as an additive and reduce the value of hydraulic conductivity. Laterite was mixed with 5, 10, 15, and 20% of GeoPOBA by weight. The test carried out were divided into physical properties (particle distribution test, Atterberg test, specific analysis, and shrinkage test), chemical (structural morphology, chemical oxides, and pH test), and engineering properties (compaction and compressive strength) of original laterite and the mixture with geopolymer. Mixture samples for hydraulic conductivity were tested using falling head compact at dry, wet, and optimum moisture content ranging from -2 and +2 of the optimum moisture content with standard proctor test. Result shows the addition of GeoPOBA as additives in laterite has significantly given positive results on soil strength and chemical alteration in geopolymerization. As GeoPOBA is mixed with the laterite, the hydraulic conductivity of laterite soil decreases from $3.08\ x10^{-8}$ to a range $3.00\ x10^{-8}$ m/s to $5.05\ x10^{-9}$ m/s. Sample above 15% of Laterite-GeoPOBA meet the requirement in designing a soil liner that gives low hydraulic conductivity, at less than $1\ x10^{-9}$ m/s. The increases in GeoPOBA content are associated with a decrease in hydraulic conductivity, leading to a significant reduction in hydraulic conductivity. An empirical model with nomograph was successfully develop from this study. The empirical model and nomograph in predicting hydraulic conductivity, *k*, were developed as alternative guidelines for engineers to design landfill soil liners without conducting laboratory testing that takes a long time and can reduce the cost and time. As an added benefit, GeoPOBA as an additive in laterite could help reduce the environmental impact of boiler ash produced by palm oil production.

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# INTRODUCTION

## 1.1 Research Background

Increased population and rapid urbanization have increased the amount of municipal waste and become challenging in developing countries like Malaysia. It was predicted that in 2025, Malaysia would be reportedly generating an immense amount of Municipal Solid Waste (MSW) around 38,699 ton/day which is equivalent to 1.17 kg/person per day (Sreenivasan et al., 2017; Yong et al., 2019). One of the preferred methods which is the simplest and cheapest way of dealing with the waste generation problems is to dispose of them in the sanitary landfills. There are 141 solid waste landfills in Malaysia with 116 are open dump sites, 21 are sanitary landfills and four (4) are residual waste landfills (Leoi, 2021). Many of these landfills have opted to close rather than opening new ones while the quantity of waste generated yearly is much faster than the natural degradation process (Masirin et al., 2008; Zakaria et al., 2018). In a very short period, more existing landfills are expected to reach their authorized capacity.

A landfill is a structure designed either built-in or on top of the ground to bury the waste in such a way that it will protect the environment by keeping the wastes separated from the surrounding soil, air, and groundwater. The main component of a landfill is the landfill liner or known as the soil liner. The soil liner is a barrier layer between waste and groundwater. The generation of daily waste has created a harmful liquid waste known as leachate. It is a crucial aspect in designing landfill to ensure that the leachate do not infiltrate the groundwater but drained into the collection tank for treatment process. According to Benson et al., (2015), a soil liner requirement is intended to ensure the structure is resistant to shrinkage cracks while constructed and in operation and has a low permeability. The leachate must not make any adverse effect on the liner material (Edopayi, 2018).

Liner system has great importance in preventing contact between leachate and environment. Benson (1995) stated that soil liner should have a maximum hydraulic conductivity of $1x10^{-9}$ m/s. In sanitary landfill, Compacted Clay Liner (CCL) and Geosynthetic Clay Liners (GCL) are commonly used as it gives low value of hydraulic