

UNIVERSITI TEKNOLOGI MARA

**THE EFFECT OF CLIMATIC
CONDITIONS ON THE
ESTABLISHMENT OF LOCALISED
CONSTANT (K) METHANE
GENERATION RATE FOR
SIMULATED MAJOR WASTE
COMPONENTS IN SHAH ALAM,
SELANGOR, MALAYSIA**

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ABSTRACT

Methane emissions from landfills must be accurately estimated to determine their greenhouse gas emissions and potential for energy generation. Current models, such as LandGEM and IPCC are unable to adapt global climatic conditions and waste compositions, which is their most major limitation. The main goal of this study is to evaluate the effects of Malaysia climatic conditions and waste composition on methane generation rate in landfills. This study used waste characterization and simulated landfill design reactors to investigate methane generation rates for several waste categories including fruit, cooked food, uncooked food, vegetable, paper, textile, garden, plastic, diapers and inorganic waste at an average Malaysian rainfall rate of 4, 10, and 20 mm/day and ambient temperature of 25°C and 37°C. From waste characterisation analysis, cooked food waste with high moisture, volatile solid and carbon content produced more methane than other waste with the value of ultimate methane generation potential (L_0) is 328.39 ml CH₄/g VS. Meanwhile, in simulated landfill design reactors, reactor with 100% paper waste produced higher methane with the total methane output is 43.78 L/kg and 91.27 L/kg at 25°C and 37°C respectively. In addition, this study found that high moisture (rainfall) and rising temperatures have a considerable impact on methane generation rates, emphasizing the need of considering these parameters when estimating emissions. To incorporate impacts of climatic conditions and waste composition in estimating localised constant methane generation rate, the lab scale data was analyzed using multiple linear regression (MLR). The backward elimination regression method was selected as the best fitted model with an adjusted R^2 of 0.673. In the selected MLR model, only eight out of thirteen independent variables were significant at $\alpha=0.1$. Thus, the MLR model showed that increasing ambient temperature, percentage of fruit, cooked food, uncooked food, vegetable, textile and garden waste lead to faster deterioration rate, but vice versa result for rainfall. In conclusion, the present MLR model capable in predicting methane generation in Malaysian landfills that received daily rainfall ranging from 4 to 20 mm with ambient temperatures ranging from 25°C to 37°C. In the meantime, this model is available for the 0-100% of six types of waste composition: fruit, cooked food, uncooked food, vegetables, textile, and garden waste. Localised L_0 and k values that were obtained from this study are 59.83 m³/Mg and 0.078 y⁻¹ respectively. Moreover, this study allowed to accurately estimate localised methane generation rate in Malaysia landfills.

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TABLE OF CONTENTS

	Page
CONFIRMATION BY PANEL OF EXAMINERS	ii
AUTHOR'S DECLARATION	iii
ABSTRACT	iv
ACKNOWLEDGEMENT	v
TABLE OF CONTENTS	vi
LIST OF TABLES	xi
LIST OF FIGURES	xiv
LIST OF SYMBOLS	xvi
LIST OF ABBREVIATIONS	xviii
LIST OF NOMENCLATURE	xxi
CHAPTER 1 INTRODUCTION	22
1.1 Research Background	22
1.2 Problem Statement	23
1.3 Research Questions	25
1.4 Research Objectives	25
1.5 Significance of Study	26
1.6 Scope and Limitations	28
CHAPTER 2 LITERATURE REVIEW	30
2.1 Greenhouse Gases Emissions	30
2.2 Methane Emissions from Landfills	30
2.3 Municipal Solid Waste Generation (MSW) in Malaysia	31
2.4 Waste Degradation Stages	32
2.5 Model-based Method in Estimation Methane Emissions	34
2.6 Existing Methane Estimation Models	36
2.6.1 LandGEM Model	36
2.6.2 IPCC 1996 Default Method (DM)	38
2.6.3 IPCC 2006 First-order Decay (FOD)	38

CHAPTER 1

INTRODUCTION

1.1 Research Background

Landfills are a significant contributor to global climate change through the emission of landfill gases (LFGs). Landfill gases comprise 50-60% methane (CH₄), 30-40% carbon dioxide (CO₂), less than 1% volatile organic compounds (VOCs), and trace amounts of inorganic chemicals, produced through anaerobic decomposition (AD) of organic waste (Duan et al., 2021). Methane is the second major components of greenhouse gases (GHGs) and it has the capability more than 22 times of trapping heat than carbon dioxide. It has a half-life of approximately 12 years, after which it degrades into hydroxyl radicals (Mathew et al., 2024).

According to Oo et al., (2024), waste sector generated 173.2 Mt CO₂e of worldwide greenhouse gas emissions. In the United States, GHGs emissions from waste sector amounted to 3% in 2022 (United States Environmental Protection Agency, 2024). Based on data from UNFCCC (2022), the total methane emissions from Malaysia landfills is 11,681.20 Gg CO₂e indicated 41.43% of emissions from the total emission in the waste sector. Between 2005 and 2022, emissions from the waste sector increased by 28.43%, primarily due to higher contributions from solid waste disposal facilities.

Accurately determining methane emissions from landfills is crucial for effective climate change mitigation. In recent years, several models have been developed to estimate the rate of methane generation in landfills. The first order decay (FOD) model is generally acknowledged as the most prevalent approach, such as Intergovernmental Policy on Climate Change model (IPCC 2006) and United States Environmental Protection Agency Landfill Gas Emissions model (LandGEM) (Alexander et al., 2005). The methane generation rate constant (k value, yr⁻¹) and ultimate methane generation potential (L_0 , g CH₄ kg⁻¹ waste) are the two principal parameters utilised in FOD models to estimate methane generation. In landfills, the methane generation rate k value represents the time taken by organic matter in waste to decay to half of its initial mass.