PREDICTING METHANE EMISSIONS OF OPEN DUMPS IN SRI LANKA FOR CARBON NEUTRALITY IN 2050

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Municipal Solid Waste (MSW) contributes to greenhouse gas (GHG) emissions, particularly methane, in Sri Lanka's open dumps. To mitigate this issue, a study was conducted to analyse methane emissions and a solution was proposed: using a daily cover combined with biochar.The analysis employs a time series analysis model to estimate GHG emissions based on demographic and socioeconomic factors such as population and Gross Domestic Product (GDP). The results show that the emissions of methane from open dumps in Sri Lanka will continue to increase due to population growth, urbanization, and economic growth. The MSW generated during the period 2021 to 2050 is expected to increase due to inadequate public commitment to waste management, lack of proper waste segregation, and challenges in implementing the 3R principles. The study proposes the use of a daily cover combined with biochar produced from MSW to mitigate landfill gas emissions. The addition of biochar demonstrates a significant impact, reducing CH_4 emissions by 50.448 CO_2-eq Gg/yr by 2050. A case study at Karadiyana dump site reported a 29% reduction in CH_4 concentration when using biochar as a daily cover. The findings of the analysis show that 10% of GHG emissions can be absorbed by the daily cover laid on the waste at the dumpsite. The time series analysis model shows good potential for estimating national GHG emissions for the waste sector with a reasonable error. The study emphasizes the importance of prioritizing and implementing proper waste management practices to effectively reduce GHG emissions from the waste sector in Sri Lanka. The inadequate waste management practices, lack of proper waste segregation, and challenges in implementing 3R principles are the fundamental problems with current waste management practices. The review concludes that the use of a daily cover combined with biochar has the potential to significantly reduce GHG emissions from MSW in Sri Lanka.

Keywords: Biochar, Greenhouse Gas, Methane, Municipal Solid Waste

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INTRODUCTION

Municipal Solid Waste (MSW) is a significant contributor to Greenhouse Gas (GHG) emissions globally. The emission of GHGs poses a major threat to the environment, leading to global warming and the greenhouse effect (Karl and Tubiello, 2021). MSW is the end point of waste in Sri Lanka, and open dumps are commonly used for their disposal. The decomposition of solid waste categories in these open dumps results in the production of methane (CH_4), which is a potent GHG. The waste management sector's activities, including transportation and treatment, are also responsible for GHG emissions.

According to the Intergovernmental Panel on Climate Change (IPCC), MSW is one of the primary sources of anthropogenic CH_4 emissions and contributes significantly to the greenhouse effect (Zeng et al., 2014). The fourth-largest producer of global emissions of non-CO_2 GHGs, MSW approximately contributes 5.5–6.4% towards global methane (550×10^6 MT) emissions annually (Maria et. al, 2020). These alarming figures highlight the urgent need for effective waste management strategies to mitigate GHG emissions.

Soil cover has conventionally been used to mitigate landfill gas emissions from MSW landfills. Methane is a major component of landfill gas, and it is a more harmful GHG than carbon dioxide. A daily cover combined with biochar produced from the MSW in the dumpsite as of figure 1 can be used to trap GHG emissions by a considerable amount. Implementing such methods would lead to significant reductions in GHG emissions from MSW and contribute towards a sustainable waste management system.

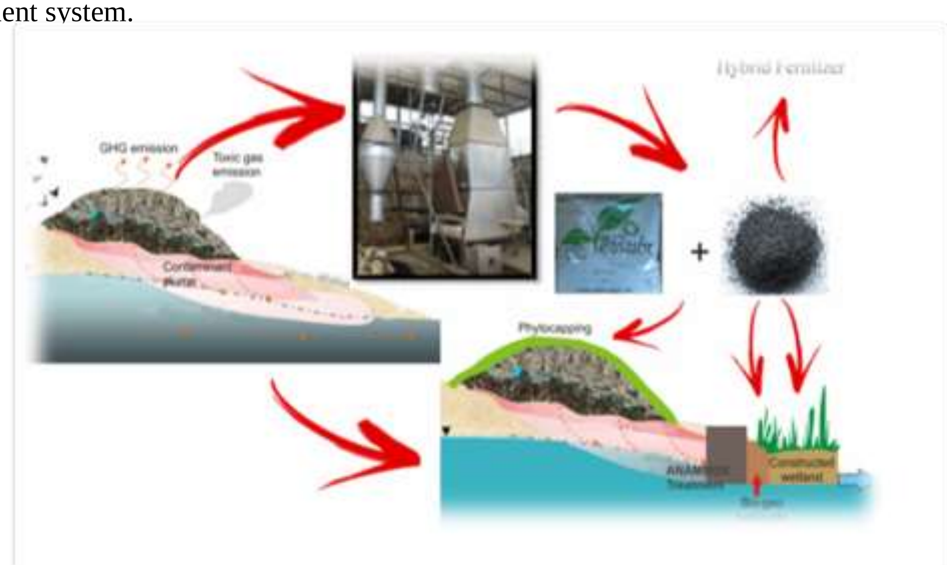

Figure 1 – Production of Biochar from MSW for the daily cover as phytocapping

The effective planning and operation of a waste management system requires a comprehensive understanding of the waste generation process, accurate predictions of waste quantities produced, and strategies to mitigate GHG emissions. This methodology combines time series analysis and regression models based on demographic and socioeconomic factors such as population and GDP to forecast future activity data. The model estimates GHG emissions based on the waste sector, and implementing techniques such as daily cover combined with biochar produced from MSW can significantly reduce GHG emissions from open dumps.

METHODOLOGY

Waste generation is a complex process influenced by several factors such as population growth, urbanization, industrialization, and changing consumption patterns. Successful planning and operation of a waste management system requires accurate knowledge of these factors and the ability to predict solid waste quantities produced. The methodology for estimating greenhouse gas emissions from waste management systems is a quantitative approach that involves collecting data, identifying drivers of waste generation, and using statistical models to develop forecasts of future waste generation and GHG emissions.

The first step in the methodology was to collect data on waste generation, population growth, and economic development. The population data from the United Nations World Population Prospect 2022 (UN, 2022) and the GDP average growth rate of 3.1% was used from the Sri Lanka Climate Prosperity Plan (CPP) Preliminary report (V20, 2022). The historical time series data were collected from the updated NDCs of the Ministry of Environment (2021).

The next step in the methodology is to identify drivers of waste generation. This can be done using regression analysis, a statistical method that identifies the relationship between dependent and independent variables. Dependent variables can be waste generation quantities, while independent variables can be population growth, economic development, and other socioeconomic factors. The regression analysis helps to develop a mathematical function that relates waste generation to the identified drivers.

Successful planning and operation of a waste management system depends on waste generation process knowledge, the amount of waste generation, and accurate predictions of solid waste quantities produced. Emission factors & Gross Domestic Product (GDP) values are based on historical time series data, driver/s can be identified for each activity data or for the sector using regression models.

GHG Emission = Activity Data × Emission Factor × GDP; Activity Data (unit) = $\sum m \times \text{Driver} + C$

Future activity data will be forecasted using the function derived by the regression model. This analysis and prediction model is based on demographic and socioeconomic factors such as population and GDP. Waste generation analysis can be done using time series data of solid waste generated quantities. The time series analysis model is used to estimate greenhouse gas emissions based on the waste sector. The population data from the United Nations World Population Prospect 2022 (UN, 2022) and the GDP average growth rate of 3.1% was used from the Sri Lanka Climate Prosperity Plan (CPP) Preliminary report (V20, 2022). The historical time series data were collected from the updated NDCs of the Ministry of Environment (2021).

Using the mathematical function developed, it is possible to forecast future waste generation and GHG emissions. The forecast can be based on demographic and socioeconomic factors such as population growth and GDP growth rates. The forecast can also be adjusted to account for planned waste reduction strategies, such as recycling programs or composting initiatives.

RESULTS AND DISCUSSION

The MSW disposed to the open dumps along with the yearly population and GDP is given in the Table 1.

Table 1 – Annual MSW disposal with Population and GDP from 2000 to 2010

Year	GDP	Population	MSW Disposed to SWDSs (Million tonnes/yr)
2000	214422.00	18777606	0.136
2001	211205.67	18911727	0.139
2002	219653.90	19062476	0.142
2003	232613.48	19224036	0.144
2004	245174.60	19387153	0.147
2005	259885.08	19544988	0.207
2006	279116.58	19695977	0.21
2007	298096.50	19842044	0.214
2008	315982.29	19983984	0.217
2009	327041.67	20123508	0.221
2010	352877.97	20261738	0.224

Considering the limitations in studies conducted in Sri Lankan conditions, a study carried out by Abraham and Xiao in 2019 in China was considered where 10% of GHG can be absorbed by the daily cover laid on the waste at the dumpsite. Further, the soil mixed with biochar and the MSW will lay a natural platform to improve the composting process within the dump. The modified soil samples were created by combining air-dried biochar and soil at a ratio of 20% biochar to 80% soil by dry mass. The grain size of the modified soil is composed of 40% sand and 60% silt. The addition of biochar greatly enhances the liquid limit and plasticity index of the soil, resulting in a classification of high plasticity silt (MH). The maximum dry density of the modified soil is 1220 kg/m^3, with an optimum water content of 33% (Abraham & Xiao, 2019).

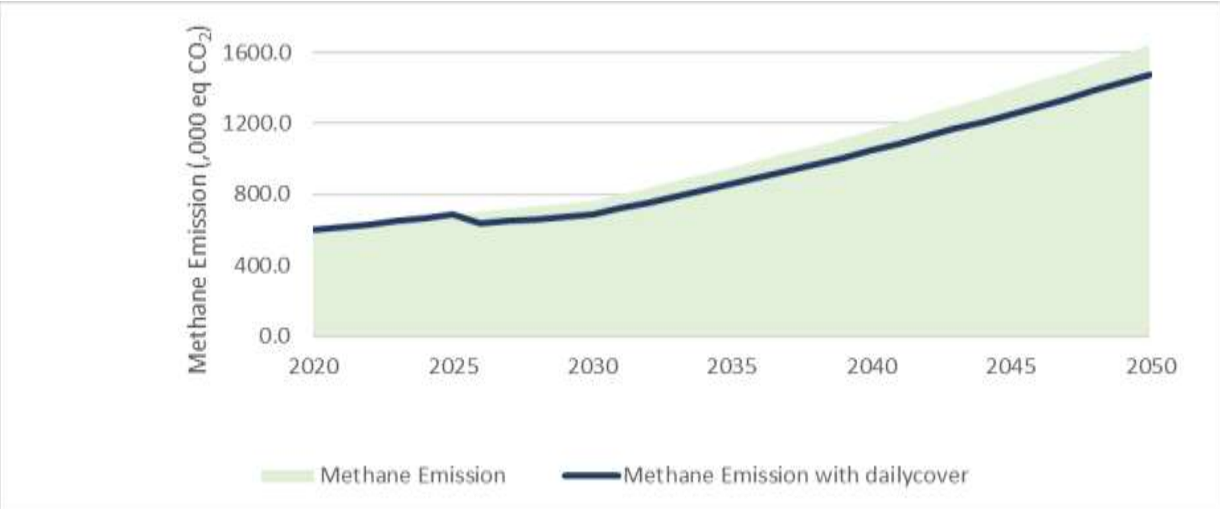

Figure 2 GHG emission from MSW, 2020 to 2050

However, the waste generation rate is expected to increase in Sri Lanka during the 2021-2050 period due to population growth, urbanization, and economic development. Figure 2 shows the GHG emission predictions from MSW up to 2050. The current waste management practices in Sri Lanka face several fundamental challenges such as inadequate public commitment to waste management, lack of proper waste segregation and adequate waste collection mechanisms covering the entire island, and practical challenges in implementing the 3R (Reduce, Reuse, and Recycle) principles.

The addition of biochar as a daily cover showed a reduction of CH_4 by 50.448 CO_2-eq Gg/yr by 2050. The findings from this research, outlined in the compelling undergraduate thesis by De Silva et al (2022), showcased a remarkable decrease of 29% in CH_4 concentration. By implementing the addition of biochar as a daily cover, this remarkable reduction in GHGs demonstrates the considerable impact this solution can have on our environment.

These challenges must be addressed to reduce GHG emissions from MSW and mitigate the impact of climate change. The waste sector in Sri Lanka presents a significant challenge to reducing GHG emissions, but with the implementation of proper waste management practices and the use of innovative solutions such as daily covers combined with biochar, there is hope for a sustainable future.

CONCLUSIONS/RECOMMENDATIONS

The waste sector in Sri Lanka contributes significantly to the emissions of GHGs, particularly methane, which is a potent GHG that can cause significant environmental hazards such as global warming and climate change. The rising trend of MSW generation due to population growth, urbanization, and economic growth further compounds this issue.

However, the findings of the study suggest that the use of a daily cover combined with biochar has the potential to reduce GHG emissions by up to 10%. The addition of biochar to soil enhances its plasticity and liquid limit, which in turn improves the composting process within the dumpsite. This not only helps reduce GHG emissions but also has the added benefit of improving the soil quality.

The results of the time series analysis model demonstrate a good potential for estimating national GHG emissions for the waste sector with reasonable accuracy. This provides a useful tool for policymakers to track and monitor the effectiveness of waste management practices in reducing GHG emissions from the waste sector in Sri Lanka.

With the potential to revolutionize our approach to mitigating climate change, the inclusion of biochar as a daily cover remarkable effective and sustainable solution. By capturing methane and reducing its harmful effects, this innovative approach represents a beacon of hope for a greener and more sustainable future.

To effectively address the growing trend of MSW generation and reduce GHG emissions from the waste sector, it is crucial to prioritize and implement proper waste management practices. This includes adequate waste segregation, waste collection mechanisms covering the entire island, and the practical implementation of the 3R principles. A public commitment to waste management is also necessary to raise awareness and encourage individuals to reduce waste and recycle.

REFERENCES

Chiu, A. C., & Xiao, Y. (2019). Physical modelling of mitigating methane emission from biochar modified MSW landfill cover. In *Proceedings of the 8th International Congress on Environmental Geotechnics Volume 3: Towards a Sustainable Geoenvironment 8th* (pp. 429-434). Springer Singapore.

De Silva, M.T.D., & Kaushalya, P. (2022). Design of Daily Cover for Mitigating Landfill Gases from Open Dumpsites. *Undergraduate Thesis*

Karl, K., & Tubiello, F. N. (2021). Methods for estimating greenhouse gas emissions from food systems.

Maria, C., Góis, J., & Leitão, A. (2020). Challenges and perspectives of greenhouse gases emissions from municipal solid waste management in Angola. *Energy Reports*, *6*, 364-369.

MoE (2021) *Updated Nationally Determined Contributions under the Paris Agreement on Climate Change Sri Lanka*, Ministry of Environment, Sri Lanka

Sri Lanka Climate Prosperity Plan (CPP) Preliminary report (V20, 2022)

UN (2022) *World Population Prospects* Department of Economic and Social Affairs Population Division Available at: https://population.un.org/wpp/Download/Standard/Population/