

UNIVERSITY OF MORATUWA

Faculty of Engineering

GPA Module CH 5407: Energy Technology

ASSIGNMENT 2

Life Cycle Assessment for Biomethane Production from Municipal Solid Waste (MSW) in Sri Lanka.

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1. **INTRODUCTION**

Municipal solid waste(MSW) is a growing problem in urban cities in Sri Lanka due to socio-economic and environmental aspects of the solid waste management systems in Sri Lanka. Municipal solid waste typically consists of short term biodegradable wastes, long term biodegradable wastes, polythene and plastic wastes, metal wastes, wooden wastes, glass wastes, paper wastes, building wastes, slaughterhouse wastes, saw dust, paddy husk, and cloth, garment wastes and other wastes. The short term bio degradable wastes of MSW consists of 50% - 60% of total waste generation in Sri Lanka and it leads different socio-economic and environmental issues in management of short term bio degradable wastes in different urban areas.

In current scenario, the short term biodegradable waste is managed through composting, landfilling and waste to energy via incineration while in a very few local authorities waste to energy via anaerobic digestion is carried out. The composition of MSW varies due to the different socio-economic and environmental aspects of people living in different local authorities such as municipal councils, urban councils and pradeshiyasabhas in Sri Lanka. Therefore, a generalized life cycle assessment model should be developed for the biomethane production from a fraction of short term biodegradable waste of MSW in different local authorities in Sri Lanka in order to consider economic viability and impact on social and environmental aspects.

The life cycle analysis is conducted using the international standard on life cycle assessment: ISO 14040 on “Environmental management - Life cycle assessment - Principles and framework” and the life cycle assessment model for anaerobic digestion developed by Paul Harris on 19th April, 2010 (Version 22.2). The statistics of municipal solid waste in Sri Lanka is taken from “Database of Municipal Solid Waste in Sri Lanka” published by Ministry of Environment and Natural Resources, January 2005 and the physicochemical characteristics of MSW is taken from the research on “Development of Performance Evaluation of the Leachate Treatment System at Gohagoda Municipal Solid Waste Disposal Site”. Through this life cycle assessment model, socio-economic and environmental aspects of anaerobic decomposition of short term biodegradable of MSW combined with composting, landfilling and waste to energy via incineration can be conducted.

1. **OBECTIVES**

* Evaluation of composition and physicochemical characteristics of short term biodegradable waste generated in local authorities in Sri Lanka.
* Development of life cycle assessment model to analyze the impact on socio-economic and environmental aspects of biomethane production from MSW.
* Evaluation of socio-economic feasibility and environmental impact of establishing biomethane production facilities on different local authorities in Sri Lanka.

1. **LITERATURE REVIEW**

MSW is a growing problem in urban cities in Sri Lanka due to absence of proper solid waste management systems in Sri Lanka [1]. According to the previous studies, it has been found that total MSW generation in Sri Lanka is more than 3000 MT per day and it increases with different socio-economic factors such as population growth, urbanization, consumerism, industrialization, etc. Effects on public health, generation of leachate which can be dissolved in natural water bodies, generation of odor, protests against waste disposal which could be a disturbance to public peace, etc. occur due to the improper waste management practices such as open dumping. Therefore, conversion of short term biodegradable waste to energy via anaerobic digestion combined with other conventional waste management strategies such as composting, landfilling, waste-to-energy via incineration could be a promising solution for the MSW problem in Sri Lanka.

Previous researches done on socio-economic and environmental aspects of biomethane production from MSW in Sri Lanka imply that physicochemical properties of short term biodegradable MSW varies according to the source separation, population growth, seasonal changes (dry and rainy season), cultural ceremonies and etc. The biomethane potential of short term biodegradable MSW changes mainly with its physicochemical properties and other factors such as feed flow rate, dilution rate, operating temperature, inhibitory effects, nutrient deficiency, etc. According to the process conditions such as input feed flow rate, the investment costs, operational costs, maintenance costs, insurance costs required for transportation, source separation, solid waste storage facilities, construction of anaerobic reactor, gas storage facilities, power generation facilities, labour force, etc. are varied. Considering the environmental impacts, wastewater treatment after anaerobic digestion, greenhouse gas emissions, odor reduction, compost generation from sludge, etc. should be evaluated. Considering the energy generation, different factors such as biogas production rate, methane composition in biogas, energy conversion efficiency from biogas to electricity, electricity required for heat effluent, etc. should be evaluated.

1. **METHODOLOGY**

Life cycle assessment (LCA) is the evaluation of the inputs, outputs and environmental impacts associated with a product system during its life cycle. According to the ISO 14040 on “Environmental management - Life cycle assessment - Principles and framework”, the LCA includes life cycle inventory analysis (LCI) phase, life cycle impact assessment (LCIA) phase and life cycle interpretation phase. In the LCI, quantification of inputs and outputs of a product system throughout its life cycle is done. In the LCIA, magnitude of potential environmental impacts of a product system throughout its life cycle is analyzed. In life cycle interpretation, findings of either the LCI or the LCIA or both are evaluated in relation to the defined scope to present the conclusions and recommendations.

Interpretation

Impact

Assessment

Goal Definition and Scope

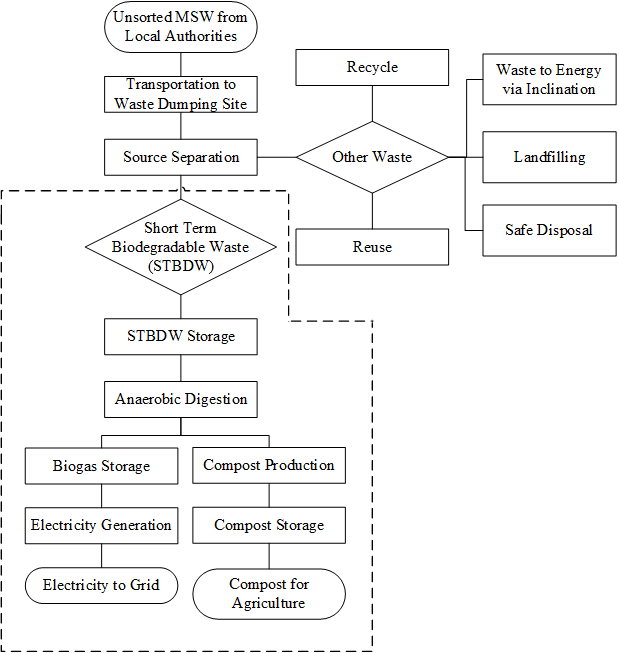
Inventory

Analysis

**Figure 1: Life Cycle Analysis Process**

* 1. **System Boundary**

The system boundary is introduced to limit the scope and specifically address the life cycle analysis of the anaerobic digestion of easily biodegradable organic fraction of MSW.



**Figure 2: System Boundary for Life Cycle Analysis for the Anaerobic Digestion of MSW**

* 1. **Life Cycle Inventory Analysis**

Life cycle inventory analysis for the short term biodegradable waste generated in Sri Lanka is done using the model for anaerobic digestion developed by Paul Harris on 19th April, 2010 (Version 22.2). The model was extensively developed further for life cycle assessment considering socio-economic and environmental aspects such as waste transportation, source separation, labour force, gas storage, compost production from anaerobic sludge, carbon dioxide emissions, etc. In anaerobic biodegradation, the input and operational conditions such as composition of the input biodegradable waste into the anaerobic reactor, dilution ratio of the input waste with water, flow rate of the input waste and process conditions such as operating temperature effect on the output conditions such as reactor size, biogas generation, electricity generation, payback period, etc.

The composition and physicochemical characteristics of short term biodegradable MSW varies in different urban areas due to source separation, population growth, social aspects, seasonal changes (dry and rainy season), cultural ceremonies, etc. The composition of provincial short term biodegradable MSW in Sri Lanka is given in Table 1.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Province | Bio-degradable waste - short term (kg/day) | Percentage of Bio-degradable waste - short term (%) | Gross weight of waste collected (kg/day) | Percentage of Gross weight of waste collected (%) |
| Western | 1040933 | 64.84 | 1662700 | 58.58 |
| Southern | 105872 | 6.59 | 198460 | 6.99 |
| Central | 139629 | 8.70 | 229223 | 8.08 |
| North Western | 58049 | 3.62 | 170189 | 6.00 |
| Sabaragamuwa | 53115 | 3.31 | 91860 | 3.24 |
| Uva | 47864 | 2.98 | 85660 | 3.02 |
| North Central | 32837 | 2.05 | 74132 | 2.61 |
| Eastern | 78357 | 4.88 | 232803 | 8.20 |
| Northern | 48695 | 3.03 | 93428 | 3.29 |
| Total | 1605351 | 100.00 | 2838455 | 100.00 |

**Table 1: Provincial Gross Weight of Waste Collection and Short Term Bio-degradable Waste Collection in Sri Lanka from “Database of Municipal Solid Waste in Sri Lanka” published by Ministry of Environment and Natural Resources, January 2005.**

In order to evaluate the life cycle analysis more specifically, one of the largest garbage dump site in Sri Lanka located in Western province is selected. The composition of biodegradable MSW arriving at Karadiyana open dump site (KODS) in Sri Lanka is given in the Figure 2. According to the extensive data analysis at KODS (June 2011 – October 2013), total daily average MSW arrived at KODS is approximately 450 tons and the total daily minimum average is approximately 364 tons.



**Figure 3: Composition of MSW Arriving at Karadiyana Open Dumping Site**

Important Information :

This plant is to be situated in the WMA’s KODS and is to take up a foot-print of 12 acres. This designed plant is capable of handling 1,000 metric tons per day (MTPD) of unsorted municipal solid waste (USMSW) to generate 6 MWe power to the national grid and also generates 100 MTPD of fertilizer from stabilized bio-solids.

The current site has been in operation for dumping since 1994 by Kesbewa and Moratuwa Municipal Councils (MC). The proponents have not been able to secure any other alternative feasible site to dispose of the solid waste with such convenience within the Urban Councils (UC) area of authority.

The infrastructure surrounding Karadiyana site such as roadways for access, the availability of road from various directions, roads with adequate average width makes this site very attractive for open dumping.

Availability of water, the readily available virgin land, and very close proximity to the national power grid makes this site an attractive location for incoming projects. There have been no threats of floods even after the Tsunami in 2004 which further uplifts the sites reputation.

From a socio-environmental stand-point, the land is centrally located surrounded by busy urban areas, yet quite isolated and disguised from the urbanization. However, isolation has not lead to lack of access which makes this land ideal for new investments along the pathways of MSW treatment.

Anaerobic digestion is the process in which organic fraction of waste converted into bio gas through biological degradation by anaerobic microorganisms. In this case study, the excel anaerobic digestion model developed by Paul Harris, April 19, 2010 (Version 22.2) is used for the optimization of anaerobic digestion process for the animal farm having three pigs and literature data on piggery waste characterization is taken from the “Optimum Operation Design Criteria for Anaerobic Digestion for Animal Manure” by D. T. Hill, 1982. The electricity selling price to the grid is evaluated by considering the electricity tariffs charges given by the Public Utilities Commission in Sri Lanka focusing the below electricity user.

* Customer type: Industrial
* Customer category I-1
* Consumption per month(kWh): Below 300 (216kWh)
* Energy charge (LKR/kWh): 10.80
* Energy selling price (LKR/kWh): 10.80\*60% = 6.48

For the PFR, the excavation cost in Sri Lanka is assumed as Rs.350.00 5000h per cubic meter and liner cost Rs.1900 per square meter.

Ref : <http://www.pucsl.gov.lk/english/industries/electricity/electricity-tariffscharges/>

Ref : <http://www.pucsl.gov.lk/english/wp-content/themes/pucsl/pdfs/ncre_tariffs%20methodology.pdf>

Capital cost for the reactor construction is generated by The Methodology for Feed-In-Tariffs - NCRE. The basis for deciding purchase tariff for energy supplied by NonConventional Renewable Energy based Electricity Generation