

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

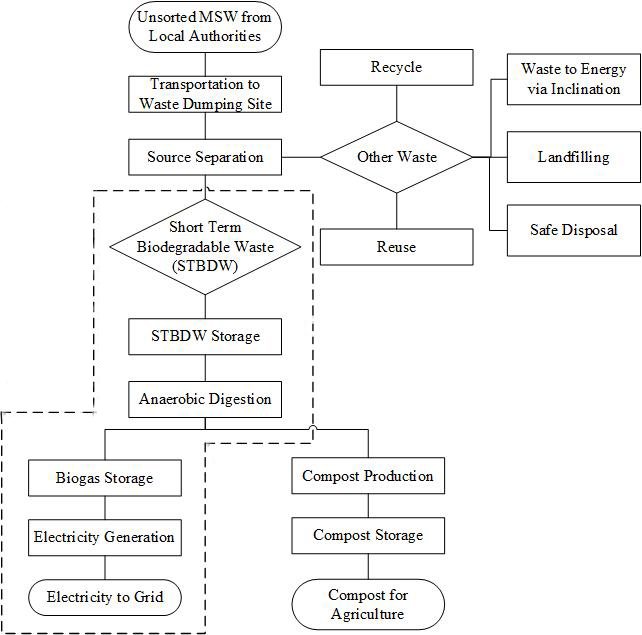
Inventory

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 average unsorted MSW arrived at KODS is approximately 550 tons per day. From this unsorted MSW arriving at KODS, food waste consists of 37.999% from the organic fraction of the total MSW has the best potential to use for the biogas and compost generation via anaerobic digestion as shown in the figure 3.

Food waste arrival at KODS = 550 tons/day \* (79.259/100) \* (37.999/100)

= 165.6470 tons/day



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

Considering the anaerobic digestion technologies, the main distinction is wet anaerobic digestion systems in which operated at low total solids (<10–20% TS) and dry systems in which operated at high total solids (>20%–40% TS). Both wet and dry anaerobic systems are successfully operated in different countries. Considering the reactor combinations single stage anaerobic digestion is more commonly practiced but two-stage anaerobic digestion is also can be applicable under controlled process conditions. The physicochemical characteristics of typical food waste from MSW is shown in the Table 2.

|  |  |
| --- | --- |
|  | Food Slurry |
| TS (g/l) | 70 |
| TVS (g/l) | 55.6 |
| Fat (%) | 3 |
| Protein (%) | 13 |
| Carbohydrates (%) | 58.5 |

**Table 2: Physicochemical Characteristics of Typical Food Slurry**

Even though the food waste of MSW contains a considerable level of moisture, the particles should be mixed with certain amount of water to make a slurry. Considering the reactor as wet anaerobic system, the percentage of solid in suspension is adjusted to 10% before anaerobic digestion. The operating temperature of the anaerobic reactor is taken as 30°C considering the average temperature of KODS and because it does not vary drastically.

According to the modified model, key parameters which directly effect on the life cycle assessment of anaerobic digestion are identified as amount of daily food waste arrival, volatile solid (VS) composition of food waste, conversion efficiency of VS into methane, methane yield, electricity conversion efficiency of the plant, tariffs for electricity produced using non-conventional renewable energy (NCRE), etc. The modified model is further developed considering the key main parameters in anaerobic biodegradation.

Considering the food waste, it typically contains certain amount of moisture. Therefore, the solid fraction of the food waste is calculated by the below equation.

The volumetric flow rate of the slurry can be calculated by considering the solid fraction of food waste generated per day and the total solid content of the slurry.

The digester volume can be evaluated by considering the volumetric flow rate of the slurry, the hydraulic retention time(HRT) and taking 10% volume as head space. This total volume can be divided into several reactors to run in parallel with each other.

The net methane production can be evaluated by considering VS input rate, VS reduction efficiency and amount of methane generation from VS destroyed.

The electricity generation rate can be evaluated by considering net methane production, calorific value of methane and electricity conversion efficiency.

Electricity Generation (MW) =

The economic evaluation is done using the costing of the anaerobic digester, costing of the power plant, costing of storage such as waste and gas storage, costing of utilities such as electricity usage of crusher, pumps and offices, operational costing such as material cost, labour cost, staff cost, water usage and etc. and maintenance costing. The payback period of the whole plant to evaluate its economic feasibility.

The net carbon dioxide emission rate can be evaluated by considering the percentage of carbon dioxide in biogas, biogas generation rate and carbon dioxide generation rate after the combustion of methane. Complete combustion of methane is considered and the reaction happens in 1:1 molar ratio. Therefore, methane supplied for the combustion is equal to the carbon dioxide generation after the combustion.

The important process parameters taken from the previous research works done one food waste from the MSW and other supportive facts are mentioned in the Table 3.

|  |  |
| --- | --- |
| Parameter | Value |
| Moisture content of food waste | 63% |
| Retention time | 20 days |
| Operating temperature | 30 °C |
| Methane percentage in biogas | 55% |
| Carbon dioxide percentage in biogas | 30% |
| Electricity conversion efficiency of the power plant | 20 % |
| Flat tariff for electricity generation from biogas in Sri Lanka | 0.18 USD |

**Table 3: Process Parameters Considered in the Life Cycle Assessment**

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>