Proposed Model For Solid Waste Management In Sri Lanka

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Abstract: The conservation of natural resources as well as for protecting the environment with maintaining quality living standards can be achieved by the proper waste management system. Sustainable development, waste elimination, minimization, recycling, reusing and replacing are playing a major role to handle waste management. Waste to energy and landfilling are the most promising technologies today. However, waste segregation is necessary to achieve the targets by filling the vacuum between households and local government authorities. The waste to energy is not much popular in Sri Lanka due to the high moisture content of the municipal solid waste. However, the pre-drying mechanism with solar heating can be applied together with bulking agents to minimize the moisture content of the waste. The rotational solar drum has been identified as the best option with minimum operating cost to implement the waste to energy process.

Index Terms: Solid waste, Sri Lanka, Landfill, waste to energy, bio gas generation

1. INTRODUCTION

Municipal Solid Waste (MSW), commonly known as trash or garbage is whatever we throw away after use for day to day applications. MSW is consisting of food waste, plastic waste, cardboard waste, metal, glass waste, wood and cloth, paint and batteries, etc. This can be generated from houses, hospitals, schools, offices, and other factories. To establish a good plan for waste management, quantity and the composition of waste disposed of should be known. Then an only a good plan can be implemented to make use of waste as a useful material without a large amount of disposal. The total amount of MSW generated around the world is approximately 2.01 billion tons per year [1]. It can be amounting to 0.74 kg per person per day of solid waste generated. Most of the low-income third world countries not managing MSW in an environmentally friendly way. Most of the countries dumping to open space or burning to remove the MSW. However, that will create serious environmental issues. It is believed to be increasing drastically within a short period.

The residents in developing countries, especially the urban poor are the most affected people by improper waste management activities. According to the literature, over 90% of waste in low-income countries are openly burned or disposed of an open dump. Poor waste management system often serves as a ground for diseases and climate change. It is important to address the proper waste management procedures immediately. Integrated waste management systems are indeed required for MSW management. Waste to energy is one of the leading solutions for municipal solid waste management nowadays. As a researcher, we are hard-pressed to find a viable environmentally sound solution for waste disposal.

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1.1 Municipal Solid Waste in Sri Lanka

Currently, an increase in the generating of MSW is caused due to population growth and increasing economic development. The total amount of solid waste generated by Sri Lanka is around 7000MT per day. However, only half of them is collected by the municipal council for proper garbage disposal procedure. The majority of the waste is generated by the Colombo Municipal area accounting for 0.8kg of solid waste per head per day [2]. There are around 120 composite sites are operating together with local government control authorities. However, with the huge amount of continuous daily solid waste generating, composting is not the only option to manage solid waste. The waste composition in Sri Lanka is given in Fig. 1 [2].

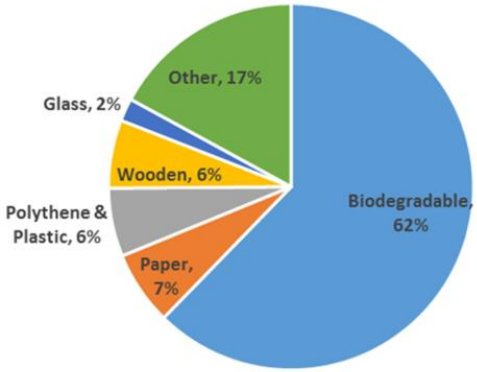

***Fig. 1**. Waste composition in Sri Lanka [2].*

It is important to handle solid waste daily basis to avoid accumulating waste without proper disposal procedure. In that case, waste to energy and landfill are playing a major role in the solid waste management process. Solid waste management (SWM) is difficult to implement as part of integrated management strategies and sustainable development in developing countries due to a lack of awareness of public and poor strategic plans. Solid waste generating is continuously increasing over the years. Therefore, the capacity of the landfill must be calculated based on the future predicted waste generating figures. Sri Lankan solid waste management system is not well established to handle the waste systematically. The most common waste handling methods are,

- Open dumping to empty land
- Compost generating

- Biogas generating plant, compost together with an open fire to burn plastic and polythene
- Landfill

Fig. 2 is representing open garbage dumping sites in Sri Lanka which was running for decades. However, open garbage dumping in Colombo has been stopped after the collapsed of one of the dumpsites called Meetotamulla in the year 2017. The man-made accident caused the death of 32 people and for the damage caused to the properties of innocent poor people living nearby.

***Fig. 2**. Garbage dumping site in Meetotamulla, Sri Lanka [3].*

1.2 Current status of waste management

In the year 2008, the Central Environmental Authority (CEA) initiated the program, "Pilisaru", to overcome solid waste problems within 10 years with the goal of waste-free Sri Lanka by 2018. However, lack of knowledgeable people and unified coherent strategy in the project handling, that was not been successful even at the end of 2019. For the last 30 years, open waste dumping in Colombo Municipal area led to the escalating issue in an unsanitary eyesore in Kolonnawa, Bluemendhal, Meethotamulla and the diminishing of wetlands, coastlines, rivers, and others streams become open dumping spaces for plastic, polythene, and hazardous waste. However, with the collapse of the Meetotamulla dumping site, the waste management process is boosted to achieve targets with Aruwakkalu sanitary landfill and waste to energy projects.

2 PROPOSED METHOD OF WASTE HANDLING

Individual households, industries, office areas, educational institutes, hospitals, and hotels together should start of waste handling to achieve the final targets. The blame-game is not the way of solving the real issue in 2019. We all are accountable for the municipal solid waste problem facing today. There should be genuine political will together with rules and regulations to implement the system. At the same time, the importance of a clean environment with natural beauty should be recognized by each individual to heading forward. As individuals we must initiate waste management at home, starting from minimizing waste generation, reducing plastic and polythene use, replace plastic and polythene with biodegradable materials, recycling waste and segregate the waste at home. The perishable (biodegradable materials) and non-perishable (glass, metal, plastic, and polythene) waste should be segregated to achieve the common targets. It should be introduced coloured garbage bags to the citizens where they will segregate according to the garbage type. Green colour bag for biodegradable food waste, blue colour for cardboard and paper, orange colour for plastic and polythene, yellow colour for hazardous waste like batteries, bulbs. However, glass and metal, wood should also be collected separately. Moreover, coloured garbage bags can be introduced to the shops and supermarkets for people to purchase at a low cost. Green colour bag : Bio-degradable waste which can be used for the compost generation, Bio gas generation, or waste to energy process.
Blue colour bag : cardboard and paper
Orange colour bag : Plastic and Polythene
Yellow colour bag : Hazardous waste, bulbs, batteries

However, the SWM process has to be implemented in the household itself to minimize the operational cost of waste handling. The first step of the waste handling is to reduce and separate waste at the household. In that case, the public should be aware of the waste separation process with coloured bags. The amount of waste reduction at source is the prime action to take for a solid waste management process. Social responsibility has to be encouraged to minimize waste handling by effectively segregate. Social awareness programs have to be implemented to spread knowledge of waste separation. In parallel, waste collection by local authorities should be implemented a proper systematic way to collect the segregated garbage bags by households. In that case, they can introduce coloured garbage bins in the common areas, city centers, hospitals, colleges, and higher educational institutes, and the government office premises. Current waste handling facilities have to be implemented and regulated to achieve their goals. Otherwise, household waste segregation will be useless if collection point segregation is not in action. Plastic and polythene collection centers should be located in every municipal area by government handling. In the process of handover plastic waste to the local center, they can earn some money based on the weight of the waste. The local councils should facilitate this process to collect plastic waste, metal and glass waste separately (Fig. 3). They can get support from metal and glass collectors in local municipal areas while earning some money to handle over the collected wastes.

***Fig. 3**. Waste Segregation.*

The clustering waste management system has to be implemented with local government administrative units, such as pradeshiya sabha, municipal council, urban councils. This clustering process can be arranged with sub-district units such as pradeshiya sabha level, or district units.

Type S: The total waste generated is less than 30 tons per day. In that case, the composting process and biogas generating units are implementing either in sub-district areas or district level. Plastic bottles and polythene waste are directly delivering to the cleaning center to clean and pack for recycling plants. One of the recycling plant located in the Horana BOI zone, "eco spindles", willingly agree to accept plastic pet bottles for their recycling plant where they produce yarn and brushes. However, glass waste and metal have to be cleaned and deliver to glass recycling and metal recycling centers. Glass and metal waste handling can be directly performed from the collection center. However, hazardous waste only should be directed to the landfill unit which can be arranged separate landfills for every province. If it is handling only hazardous waste, there will not be any leachate problems with the landfill unit.

Type M : Total waste generated is between 30 - 100 tons per day. In that case, it is better to use the waste for waste to energy process. However, hazardous waste can be directly sent to the landfill site. It must be handled through the district base where waste generated by several municipal councils together should operate the landfill unit.

Type L : This type L cluster is for daily waste generation is higher than the 100 tons. It is compulsory to use this waste for waste to energy sites. There should be landfill together with waste to energy site. Daily generated waste should be daily supply as input for the waste to energy plant. Once again hazardous waste should be directed to landfills.

It is always better to handle this category for the provincial sector. When the total waste generated by that sector is higher than the 100 tons per day, those waste should be directly sent to the provincial waste to energy plant and landfill site. All the municipal areas where daily average waste generating is higher than 100 tons should handle together to perform the waste to energy process.

Once local or district waste generating is exceeding the total amount, they can directly work together with the cluster L. Each local administrative body should have a waste management committee to handle the waste correctly.

It is very important to implement the public awareness program to educate the people for a better waste separation process. Public participation is necessary to achieve a proper waste management system. It should be clearly stated from the primary school, secondary schools, and further, develop for higher education institutions together with necessary technical knowledge.
Here the basic information related to the landfilling and waste to energy process is discussed.

2.1 waste to energy

Waste to energy is a widely discussed topic at the present. The most important factor with the waste to energy process is capable of energy generation with waste handling. Waste to energy can be mainly divided into two ways, Thermal and Biological procedures [4]. Thermal - Thermal process consists of combustion, gasification and pyrolysis.
Biological - Anaerobic digestion (AD)

2.2 Combustion

Direct combustion is the most established process of thermal waste to the energy system. The majority of the plants are recovering heat from flue gases via industrial boilers to generate steam. That generated steam use to generate electricity with a turbine. The combustion process maintains with the excess amount of oxygen to heat the waste without any pretreatment process.

2.3 Gasification

Gasification is not widely applicable for waste to energy process. The gasification process takes place in a restricted oxygen environment to generate synthesis gas (Syngas).

2.4 Pyrolysis

Pyrolysis is defined as thermo chemical decomposition of organic waste material at higher temperatures (400-900°C), absence of oxygen or other reagents [5].

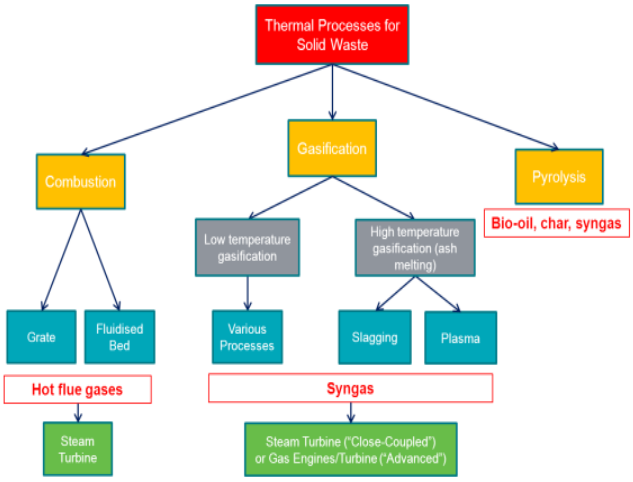

Fig. 4*. Thermal treatment of solid waste [6].*

Fig. 4 is representing the thermal treatment of solid waste [6]. The net electrical output of the waste to the energy combustion process varies between 15 and 25%. The low calorific value raw materials has been identified as the main reason for low efficiency compared to the fossil fuel-based power plants [6]. The most viable method is considered as a direct combustion (incineration) process to generate the heat.
Nowadays, the waste to energy technology is the most attractive technology as a favorable waste management technology. It seems to be the most promising technology as it is producing alternative energy while diminishing the volume of waste. While discussing waste to energy technology for waste management, it is directly helping for producing energy to daily use by reducing fossil fuel-based energy production. In that case, environmental pollution by fossil fuel can also be minimized. Waste to energy is a waste treatment to produce electricity, steam or heat by using waste as a raw material. The majority of the household waste generating in Sri Lanka is related to food waste. At the same time, the moisture content of the waste is comparatively high. Therefore, it may require a high amount of energy to start the incineration process and

perform. Therefore, it is better to use the preheating mechanism before the waste to energy incineration process. The moisture adversely affects the efficiency of the energy generation process as the process consumes more energy to evaporate moisture from MSW. Therefore, waste to energy process receives less attention in tropical countries like Sri Lanka. Even though pre-heating is the most appropriate technique to reduce moisture content in the solid waste, it consumes extra energy. Therefore, solar energy is more effective to apply for pre-heating solid waste before feeding to the waste incinerator. It can be pre-heated with solar rotational drum or solar-heated dryer. In both methods, solar energy can be converted to thermal energy together with air intake to generate hot air and remove the moisture content or reduce the moisture content of the waste. At the same time, the solar-powered electrical dryer can also be applied for the pre-heating section. As Sri Lanka is a tropical country, that would be interesting to utilize solar energy for waste to energy project.

2.5 Landfill

The sanitary landfilling is considered as the primary conventional method of solid waste disposal [7]. The solid waste dumped into landfill site gradually release its initial interstitial water and by-products of the decomposition process. The liquid which is released by landfills is consists of innumerable organic waste as well as inorganic compounds. The liquid released by the landfill is called leachate. This leachate gradually accumulates at the bottom of the landfill throughout the period and percolates through the soil. The potential pollution by release leachate is having a high impact on nearby water resources. It is clearly showing that surface and groundwater resource contamination of nearby area is high around landfill sites based on the recent studies. There should be an impermeable liner and drainage system at the base of the landfill to prevent leachate percolate into the subsoil. All the leachate accumulated at the bottom of the landfill should be taken out through the drainage system to separate tank for the further treatment process. However, the total moisture content of solid waste feeding to landfill sites should be maintained at a low level to minimize leachate accumulation. Therefore, solid waste should be compressed before feeding to the landfill site. At least that will help to reduce the initial interstitial moisture content of the solid waste [8, 9, 10]. It is very important to reduce biodegradable waste use for landfills. The main reason for that is, biodegradable waste can be recycled, use for biogas generation, composting plants, waste to energy plants to recover thermal energy. As there are several options before landfill, it must be taken into consideration while biodegradable waste are handling. The waste hierarchy can be applied to any country around the world for the waste management process. The waste hierarchy is given in Fig. 5 [11]. According to the waste hierarchy, waste prevention is prioritized and implemented while disposal to be managed as the lowest priority.

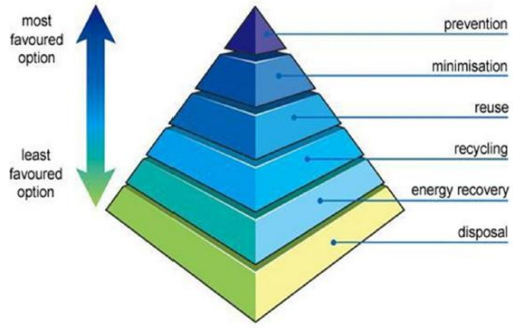

***Fig. 5**. EU waste hierarchy.*

The most important advantage of shifting municipal solid waste management up in the hierarchy are more efficient resource use as well as a reduced waste burden on the natural environment. The proper waste management system will directly contribute to greenhouse gas emission reduction. Landfill gas can be generated by volatile organic matters, reactions of waste material or by the decomposition process. Landfill gas consists of methane (CH_4) and carbon dioxide (CO_2), approximately 55-60 % of CH_4 and 40-45 % of CO_2 [12]. However, CH_4 is considered as the greenhouse gas with a higher potential impact compared to CO_2 [13, 14]. The landfill is responsible for 5% of overall global greenhouse gas emissions while 18% of CH_4 emissions to the environment [15]. However, CH_4 can be collected for energy purposes and use to generate electricity, cooking purpose or heating applications. At the same time, methane can apply to the transportation sector. However, if it is difficult to collect, it should be flared off. The overall picture of the landfill CH_4 gas is given in Fig 6. At the same time, biogas generation plants also can be connected with the same applications. During the process of biogas generation, methane can be collected and use for cooking purposes to replace LPG, the transportation sector, or the power generation sector. It can be applied biogas generation together with landfill gas as a combined project.

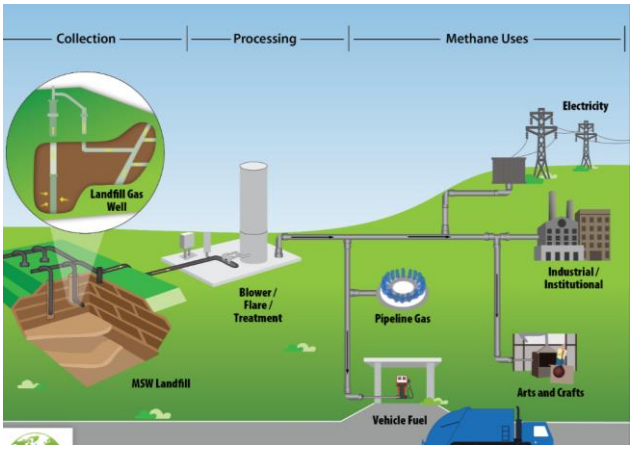

***Fig. 6**. Methane utilization of the landfill gas [16].*

One of the main problems with landfills is to maintain the leachate coming out from the landfill site. It should be pre-treated on-site to meet the standards for its discharge into the environment. Several factors are affecting on leachate

production. The main contributor to generate leachate is the rainfall. The water percolates through the solid waste and dissolve part of the waste and accumulate at the bottom of the landfill. However, decomposition of the waste also produces leachate up to some level while surface water runoff also plays a significant role. The total amount of leachate can be reduced only if waste is compressed before entering the landfill site as compaction reduces the filtration rate. The location of the landfill site is important when considering the total amount of leachate production. In arid climates, the landfill will produce a limited amount of leachate mostly in the rainy season if it is compressed enough. Annual rainfall of fewer than 400mm areas is much better for leachate control [17].

3 OBJECTIVES

According to the literature, it is clear that the majority of the waste to energy plants is the combustion process. The most common issue with the waste to energy combustion process is less efficiency of the energy generation. Therefore, it is important to increase the efficiency of the process. All Waste to energy combustion plants generate high-temperature flue gases and generate steam to produce electricity. A proportion of the electricity generated is directly used for internal plant requirements and remaining will be exported to the grid.
Waste to energy plants can be classified into four main categories based on the net outcome.

- Electricity only
- Electricity and heat (combined heat and power)
- heat only
- Generating Syngas which is secondly used for producing vehicle fuel.

However, the demand for heat in tropical countries like Sri Lanka is very less compared to European countries. Therefore, the most viable option is to generate "electricity only" by waste to energy combustion plants. The most common issue is to increase the overall efficiency of the process. The efficiency of the combustion process is defined as gross efficiency and net efficiency according to the outcome. Gross efficiency – can be defined as an electrical power produced by the generator as a proportion of the total energy input to the plant
Net efficiency – can be defined as an electrical power exported by the plant (excluding power consumed by the plant itself) as a proportion of the total energy input to the plant.

Research areas to complete:
Therefore, it is very important to increase the net efficiency of the process. To achieve the targets, type of waste, properties of the waste, moisture content, calorific value, content of the waste should be analyzed. Waste to energy plants technically prevents methane emission to the environment due to the anaerobic digestion process or by landfilling. However, it should be analyzed that flue gas emission to identify the emission content after the combustion process. The amount of carbon dioxide emission has to be analyzed after the combustion process, i.e. flue gas emission due to waste incineration. It is important to compare the overall emissions of CO_2 by the combustion process of the waste to energy plant and CO_2 savings that would otherwise, be produced by fossil fuels (especially coal). To achieve the high efficiency of the process, other operating parameters have to be implemented. As an example, combustion temperature, pressure of the incinerator, retention time, waste feeding flow rate should be analyzed to understand the optimum values to get higher efficiency. The final objective of the waste to energy process is to improve the overall efficiency of the process to 40%. Moreover, the fly ash of the combustion process has to be analyzed. Most of the common way of handling fly ash is to transfer that to a landfill site. However, the quantity of fly ash should be minimized to reduce the volume of the landfilling. At the same time, fly ash will consist of unburned metal and glass, plastic material, partially burnt waste and toxic material. Therefore, it is at risk to apply fly ask for agricultural purposes. The total volume of the fly ash must be minimized and analyzed before the landfilling process. It is important to reuse the fly ash for other industrial applications to minimize the landfilling amount. Therefore, research studies should be performed to reuse of fly ash for different applications.

It has been identified, the reuse of bottom ash in construction has several benefits:
■ Reduction in material to landfill
■ Reduction of primary aggregate use and the associated reduction in CO_2 emissions
■ Additional revenues from the sale of ash

The flue gas emission from the combustion process has to be pretreated before release to the flue gas stack. Emission of the flue gas content should be analyzed together with the waste composition and moisture content.
The total cost associated with the waste to energy process plant is (waste reception and handling, furnace, and boiler, flue gas treatment, energy recovery system);
■ Civil and building works;
■ Utility connections;
■ Design, procurement and project management costs;
■ Planning and permitting;
Therefore, research has to perform to minimize the operating cost of the process.

Industrial Automation system, Programmable Logical Controller (PLC) unit together with the industrial process has to be implemented to achieve the highest efficiency of the process. Temperature, moisture content and the pressure of the waste to the energy system and landfill should be continuously analyzed to maintain properly. One of the main environmental problems caused by landfill is odour. That can be connected with gas emissions due to biodegradable materials and volatile organic matters. Landfill gases consist of some amount of hydrogen sulfide (H_2S) as well. If wet-waste material is keeping for a longer time period before feeding to the landfill site, that will spread the odours and will often permeate the neighborhoods. If the landfill site is accepting medical waste, toxic waste and hazardous materials, the household should be located after a certain distance only. It is not significantly live closer to the landfill site. However, this will directly link to the category of the landfill site. However, before thinking about waste management, zero waste is the best option to go forward. The waste hierarchy should always be followed for every production process. If it is difficult to eliminate, minimization is necessary. Instead of plastic and polythene products, biodegradable products have to be replaced immediately to maintain a better living environment. Government authorities have to play a major role in order to recycle more and more materials and to properly maintain the segregated waste collection process. Plastic, polythene, metal,

the glass should be directed to recycling plants. Waste collection points should be established in every municipal council area to fill the gap between household collecting and recycling centers. The general public should be easily accessible to waste collecting centers. Plastic, metal and glass waste should be the value at the collection centers to promote the people towards the segregated waste collection system. The waste management system should be the service with profit generation. However, Sri Lankan government authorities are highlighting the high moisture content of the solid waste will lead to the demotion of the waste to energy process. As more heat requires for the moisture evaporation process, it has been calculated as Rs.35 per unit generation is required for waste to energy process which is higher than the Ceylon electricity board normal power generation rates. However, one thing should be kept in mind, waste to energy is not an energy-generating power plant. That is a waste management site which can be used to generate energy. In that case, waste issues are solving by producing electricity or energy. Therefore, even at higher rates, it is good to continue waste to energy processes. Moreover, the majority of the electricity generating in Sri Lanka is doing by the coal-fired power plant and thermal power station where both of them are running by fossil fuels which are imported by foreign countries. Therefore, foreign revenue can be saved within the country with waste to energy process rather than spending for outside fossil fuel purchasing. Therefore, Rs. 35 per one unit generation also acceptable as saving the foreign revenue by handling the municipal solid waste. However, the high moisture content of the solid waste, MSW, can be minimized by the preheating process. That can be easily done by a solar rotational drum which is running with solar energy to generate hot air to evaporate the moisture of the MSW. Therefore, extra electricity not necessary to reduce the moisture content of the MSW in the waste to energy process. However, there are other drying technologies also available. The most common drying techniques for moisture reduction of MSW is given as,

a. Biodrying
b. Biostabilization
c. Solar Drying
d. Thermal Drying

However, solar drying is preferred due to less energy requirement, solar energy is available throughout the year, less operating time despite the high capital cost. The rotational drum is the best method to remove the moisture content of the MSW as it will mix the waste to circulate hot air properly. The suited temperature range of the solar drying process is 50–60°C. Bulking agents such as wood chips, rice husk, and straw, corn cobs, plant leaves can be directly mixed with MSW to reduce the moisture content by increasing the pore spaces between the waste material. That will be improving the oxygen flowing within the waste pile [18].

4 CONCLUSION

Waste management is important to maintain a quality living environment. Waste segregation at the generating place is necessary. Local authorities should be taken the necessary action to prevent waste open dumping and improve the collection process. Waste minimization, reuse, replace, elimination are the most important part of the solid waste management process. However, sorted waste can be clustered based on the total weight and directed to waste handling sites, where biogas generation, composting, waste to energy process and landfills are plays a major role. The high moisture content of the Sri Lankan MSW can be minimized by the solar heating process as a pre-heating technique to implement the waste to the energy process. Carbon sources such as wood chips, leaves, rice straw, corn cobs can be used to minimize the moisture content as bulking agents by promoting pore spaces allowing more oxygen to flow through the waste pile. However, the type of the bulking agent, feeding rate, initial conditions of the waste, should be analyzed further. However, the solar drying mechanism can be reduced the moisture content by 100% allowing reduction of the weight and volume. The capital cost of the dryer should not be considered as it will directly open the several advantages by minimizing MSW, generating energy and reducing fossil fuel-based power generation, reducing GHG emissions by open dumping and landfilling, reducing transportation cost of the MSW (only if drying process has taken place at the origin of the waste).

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