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POWER GENERATION FROM REFUSE DERIVED FUEL

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Abstract. The beginning of the third millennium has been characterized by a progressive increase in the demand for fossil fuels, which has caused a steep rise in oil price. At the same time, several environmental disasters have increased the sensitivity of world-wide public opinion towards the effect that environmental pollution has on human health and climate change. These conditions have fostered a renewed interest in renewable energy like solar energy, wind energy, biomass and solid wastes. In addition, the disposal of municipal solid waste (MSW) has become a critical and costly problem. The traditional landfill method requires large amounts of land and contaminates air, water and soil.

The increase in socio-economic condition during the past ten years has also significantly increased the amount of solid waste generated. There are around 1200 tons of municipal solid waste (MSW) generated daily, of which the combustibles namely plastics, paper and textile waste represent 28%. The study was, therefore, initiated to assess the potential of power generation from refused derived fuels (RDF) from municipal solid waste (MSW) in order to reduce the dependency on fossil fuels.

There are 336 tons which is equivalent to 12 tons/h of RDF that can be generated daily from the MSW and this would generate 19.2 MW power. There will be 312 kg/h of ash that would be generated and the NOx and SO2 concentration were found to be 395.5 and 43.3 mg/Nm3 respectively which is below the EU standard.

Keyword: Municipal Solid waste, Refuse Derived Fuel, Waste to energy

1. Introduction

Energy is one of the most basic of human needs and it drives human life and is extremely crucial for continued human development. Throughout the course of history, with the evolution of civilizations, the human demand for energy has continuously risen. The accomplishments of civilization have largely been achieved through the increasingly efficient and extensive harnessing of various forms of energy to extend human capabilities and ingenuity. Providing adequate and affordable energy is essential for eradicating poverty, improving human welfare and raising living standards worldwide. The global demand for energy is rapidly increasing with increasing human population, urbanization and modernization. The growth in global energy demand is projected to rise sharply over the coming years and as such the world heavily relies on fossil fuels which is limited to meet its energy requirements. Therefore, other forms of energy which are sustainable need to be found.

MSW has a very good calorific value which makes it a good source of energy. MSW power plants which are also called waste to energy plants are designed to dispose of MSW and to produce electricity as a by-product in an incinerator. Refuse derived fuel (RDF) from municipal solid waste can be an alternative form of energy to replace fossil fuels. RDF is the component of MSW that has higher calorific like paper, plastics and textile.

The combustion of RDF in WTE facilities is a widespread practice with a trend towards increased growth in the International Energy Agency (IEA) and International Solid Waste Association (ISWA) member countries.

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2. Solid Waste generation in Mauritius

Mauritius is a small island developing state situated in the South-West of the Indian Ocean at latitude 20^{o} south and longitude 58^{o} east with a total land area of 1,865 km^2. It was formed through a series of basaltic lava flows. Before its discovery and colonization, it was uninhabited. It has many areas of fertile land formerly heavily wooded and rich in endemic species. The population was estimated to be around 1.27 million inhabitants in 2009 [1].

The Mauritian economy has done remarkably well over the past three decades. Since independence in 1968, it has experienced significant transformation from an economy that was almost entirely dependent on sugarcane cultivation and manufacturing to one that has benefited from an export-led strategy. Industry, in particular, clothing and textile manufacture, constituted a cornerstone of the economy until recently. Global business (offshore) and Freeport activities have also been growing continuously since the mid 1990's. The economy in 2009 grew by 2.2% and the Gross National Income per capita at market price reached 275,644 Mauritian Rupees (MUR). The GDP has also gone from 264,889 million MUR in 2008 to 274,819 million MUR in 2009.

The rapid economic growth achieved through industrialization and urbanization, coupled with a general improvement in the standard of living, has brought about socio-cultural changes in terms of population and consumption pattern. Consequently, the volume and nature of waste generated by the various sectors of economy have changed considerably.

Generation of MSW refers to the quantity of materials and products before any treatment like recycling (including composting), incineration and landfilling of waste [2]. The quantity of generated solid waste mainly depends on population and people's living standards, income level, economic growth, consumption pattern and institutional framework. Generation of MSW is identified as an inevitable consequence of production and consumption activities related to the level of income and urbanization [3]. The quantity and characteristics of MSW are two major factors that are considered as the basis for the design of efficient, cost effective and environmentally compatible waste management system.

The solid wastes generated in Mauritius include all the garbage created by households, commercial sites like restaurants, stores, offices and institutions. Scott *et al* (1993) [4] conducted a national survey on the amount of waste generated in 1993. They gave a volume of 600 tons of waste generated daily. This value has increased significantly as the present generation rate has almost doubled, which is around 1,200 tons per day [5]. The rate of waste generation is increasing such that the present amount of waste generated is more than that projected by Brown *et al* (1997) [6] for the year 2010, which is 1,145 tons per day. With the rising incomes, it is being forecasted that the quantity of solid waste generated will continue to increase.

Solid waste composition varies substantially with socio-economic conditions, location, season, waste collection and disposal methods, sampling and sorting procedures and many other factors [7]. The composition and type of refuse not only vary from location to location, but also from householder to householder. Even domestic refuse from a single house will vary from week-to-week and from season-to-season. Despite the variability in its composition, the organic fraction constitutes the highest percentage of solid waste [8]. Bunjun (1982) [9] carried out a study at the University of Mauritius to determine the composition of solid waste only in the urban areas and found that organic waste consisted of 60% of the solid waste. Another study carried out by Brown *et al* (1997) on a national basis showed that organic waste was the dominant one. Mohee (2002) [10] conducted a study on the recovery potential of solid waste in Mauritius and she found that vegetable and food wastes from the kitchen and yard wastes accounted for more than 60%. The composition of the different components of municipal solid waste obtained is shown in Figure 1 [11].

The dominating fraction is organic waste which consists of yard waste, kitchen waste and waste paper. Yard waste constitutes 43%, kitchen waste represents 23% and paper represents 12 % of the MSW. This implied that 80% of the MSW is organic waste. Plastics wastes constitute 13 % of the MSW, metal and glass represent 1% each. The remaining part consists of 1 % metal and 1% glass and 2 % inert material which is non-combustible and non-biodegradable.

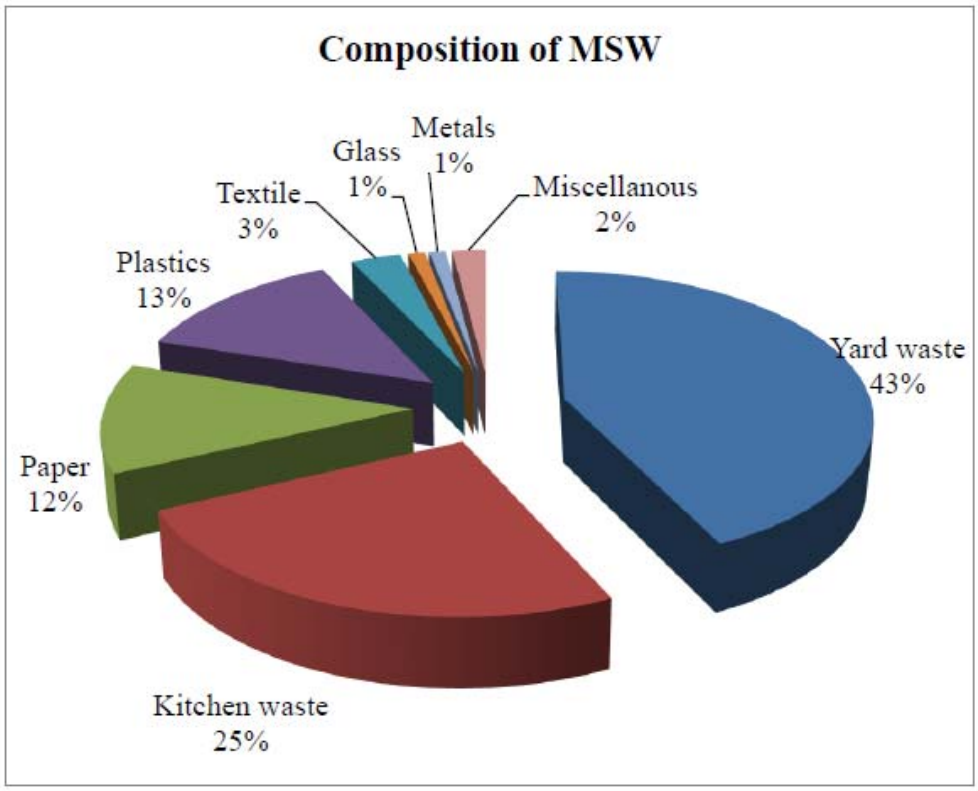

Figure 1: Composition of Municipal Solid Waste

3. Solid waste disposal in Mauritius

MSW treatment is one of the most vital issues in the contemporary urban environment particularly in many developing countries. In the last two decades, MSW management became a major concern and is presently one of the main public subjects under discussion. This is probably due to the considerable increase of MSW production. The collection, transport and disposal of MSW are all important aspects of waste management for public health, aesthetic, and environmental reasons.

Wastes disposal methods in Mauritius have changed considerably due to environmental and health awareness. Long ago, solid waste was disposed of in dumping grounds, but due to public complaints of the inconveniences caused by the foul odor emitted by the putrefying waste, all the open dumps have been closed. Today, solid waste are collected and disposed of at transfer stations and landfill.

Collection of solid waste is carried out by using various types of vehicles, with the type of vehicle depending on the type of collection and width of the road. It is the responsibility of the local authorities to collect all the municipal solid waste in their respective jurisdiction. The local authorities have their own trucks and labour force to collect the waste, but due to large amounts of waste, the service of some private companies are also hired for the collection of the waste. Both trucks from the local authorities and private companies are responsible for collecting waste from every waste collection point in an area and transporting the waste to transfer stations and disposal sites.

4. Methodology

Preliminary analysis namely gross calorific value, moisture content and ash content of each component of MSW were conducted on the samples before undergoing incineration. The CHNS was also determined for some of the components. Mass and energy balance were then done on a RDF to energy facility to determine the amount of heat and power generated. The amount of ash and the concentration of SO_2 and NO_x were also conducted.

5. Findings

Models were developed using mass and energy balances on an waste to energy facility. The models were developed based on input-output analysis such that they could be used to forecast or predict the amount of product or output from incineration. The models in the incineration option were used to predict the amount power that would be produced from RDF, the amount of ash generated and the concentration of SO_2 and NO_x. The different parameters used to input in the models are shown in Table 1. The higher heating value of RDF is 23.97 MJ/kg, moisture percent is 8.54% and the ash content is 2.94%.

Table 1: Parameters used as input to predict output of MSW and RDF system

		Unit
RDF		
C	49.98	%
H	7.53	%
N	0.58	%
S	0.16	%
O	38.80	%
Moisture content	8.54	%
Ash percent	2.94	%
HHV	23.97	MJ/kg
Efficiency of NO_x cleaning equipment	85	%
Efficiency of SO_2 cleaning equipment	90	%
Efficiency of boiler	90	%
Efficiency of steam turbine	33	%

The outputs of the models for combustion system using RDF are shown in Table 1. Usually an excess air of 20 to 150 % is recommended for the combustion of MSW[12]. However, an amount of excess air of 40% was used in this study. Too low level of air results in incomplete combustion and too high level of excess air reduces the temperature inside the combustion chamber which may result in undesirable compounds.

It can be seen from Table 2 that the amount of thermal energy generated is 58.1 MW and the amount of power is 19.2 MW. The amount of energy per unit weight that is generated from RDF was 4.15 kWh/kg. The limit for NO_x is 400 mg/Nm^3 as per the EU Directive 2000/76/EC and therefore it can be seen that the NO_x emission from RDF complies with the limits. The emission for SO_2 is 50 mg/Nm^3 as per EU Directive 2000/76/EC and hence the emission from RDF complied with the limits.

Table 2: Input and output of waste to energy system

	RDF	**Unit**
Input		
Flow rate of feed	14,000	kg/h
Flow rate of air	77,104	m^3/h
Output		
Ash	312	kg/h
Emissions		
NO_x	395.5	mg/Nm^3
SO_2	43.3	mg/Nm^3
Energy		
Thermal	58.1	MW
Power	19.2	MW

6. Conclusion

Refuse derived fuel (RDF) from municipal solid waste can be an alternative form of energy to replace fossil fuels. RDF is the component of MSW that has higher calorific like paper, plastics and textile. The

combustion of RDF in WTE facilities is a widespread practice with a trend towards increased growth. RDF generated from MSW in Mauritius has a higher calorific value of 23.97 MJ/kg. The moisture percent is 8.54% and the ash content is 2.94%.

The amount of thermal energy generated is 58.1 MW and the amount of power is 19.2 MW. This implies that 4.15 kWh of heat is generated per unit weight of RDF 1.37 kWh electricity per unit weight of fuel. Combustion of RDF releases emission and it was found that both the NO_x and SO_2 complied to the EU Directive.

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