C2_Energi Recovery Potential from Combustible Fraction of Semarang’s Municipal Solid Waste

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RESEARCH ARTICLE

Advanced Science Letters
Vol. 23, 2424–2426, 2017

Energi Recovery Potential from Combustible Fraction of Semarang's Municipal Solid Waste

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Generation of municipal solid waste (MSW) in Semarang increased rapidly. Meanwhile, the capacity of municipal solid waste management to collect waste appropriately and safely was showed a declining trend. With a lack of appropriate landfill site, waste-to-energy processes were viewed as the preferred methods to reduce the amount of MSW disposed to landfills. The objective of this paper was to evaluate the energy recovery potential from MSW in the form of electricity and heat generation as a result of the implementation of incineration. The waste composition is determined using a method based on a national standard Indonesian and American Society for Testing and Materials. The ultimate and proximate analyses were carried out according to American Society for Testing and Materials. Based on these analyze, the total energy could be generated 8.685 MW nearly 1.14% of the gross Semarang energy consumption. The preliminary results showed that it was possible to recover MSW as a source of renewable energy.

Keywords: Energy Recovery, Landfill, Municipal Solid Waste, Waste Composition, Waste to Energy.

1. INTRODUCTION

Indonesia is the world's fifth most populous country. The population of Indonesia in 2025 reached 285 million, increased from 255 million in 2015.[1] Indonesia generates 127,500 tons garbage each day with assumption every citizen produce 0.5 kilograms MSW a day. These amount estimated to rise with increasing population, urbanization growth, community habit, and the rise of standards of living. Appropriate waste management has been a big challenge in most developing countries[2] like Indonesia. There are three methods to MSW treatment: thermal treatment, biological treatment, or landfilling.[3] Landfill method currently used for the final disposal of MSW in Indonesia. There are 460 landfills with total capacities 23,204 tons/day but only 10% sanitary landfill.[4]

Semarang city is the capital of Central Java Province, the fifth most populous city in Indonesia. MSW was generated 1200 tonnes/day, transported 800 tons/day to the Jatibarang landfill. Jatibarang landfill operates 90% open dumping. The open dumping landfill contributes several problems for public health and the environment such as water pollution by leachate, gas emissions methane gas (CH_4), a more potent greenhouse gas than carbon dioxide (CO_2), and odors.[6,7] Jatibarang landfill has been operated since May 1992, which its service time was already over in 2008.[8] The service time of the final dumping site could be extended with some modifications because of the difficulty to find a new location. With a lack of appropriate landfill site, waste-to-energy (WTE) processes are viewed as the preferred methods to reduce the amount of MSW disposed to landfills.[9] WTE is promising technology has received increasing attention over the past two decades due to the increasing demand for clean fuels and chemical raw materials and the need to reduce dependence on fossil fuels, reduce emissions of greenhouse gasses and dispose of existing waste. Combustion processes, generally called incineration are the most popular approaches of WTE.[10]

Incineration is a process aimed at obtaining complete combustion of all species are suitable elemental contained in the feedstock. For the first MSW incinerators, energy recovery was not a goal; they were built for hygienic and volume reduction reasons.[10] In recent decades, the primary interests toward thermal treatments were due to their ability to significantly reduce the solid waste in mass (about 72–100%), allowing preserving landfill space, provides a source of renewable energy. The most typical energy products produced at these facilities are steam and electricity. In modem countries, energy from MSW amounts to around 5% of the total energy demand.[11] The efficient utilization of this energy thus can reduce the need for other energy carriers such as fossil fuels.

Thus, the objective of this paper was to evaluate the energy recovery potential in the form of electricity generation and heat from the baseline study in Semarang represented by

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 1936-6612/2017/23/2424/003 doi:10.1166/asl.2017.8681

existing landfills that would result from the implementation of incenerator.

2. OVERVIEW OF ENERGY SITUATION AND GREENHOUSE GAS EMISSION

2.1. Final Energy Consumption

In Indonesia, the average population growth in the period 2000–2013 was 1.66% per year. Meanwhile, energy consumption (including biomass) increased from 764 million BOE in 2000 to 1,151 million in 2013. Electricity consumption had an average growth of 6.8% per year during the period 2000-2013, thus the national electrification ratio that only reached 80.4% in 2013. It means that 19.6% of the Indonesian population has not been electrified yet.[12] The planned 35 thousand MW power plant of Indonesia government is expected to meet the shortage of the electrification and stimulate the national economy.

To meet the national electricity demand the Indonesia Government will accelerate the implementation of the development of waste to energy by developing waste-based power plants in seven[7] cities as a pilot project, i.e., Jakarta, Tangerang, Bandung, Semarang, Surakarta, Surabaya, and Makasar. Until now, garbage is seen as a source of the problem, not a valuable matter. The achievement waste to energy in Indonesia just reached 17.6 MW while the potential is about 2,066 MW.

2.2. Greenhouse Gas Emissions from Energy Sector

Indonesia is among the world's ten largest emitters of GHGs. The energy sector is the biggest contributor greenhouse gas (GHG) emissions, primarily CO_2. The transportation, industrial, commercial, and household emission contributed 18.47 million tons, 73 million tons, 54 million tons, and 178 million tons per year respectively.[13] The Indonesian government established a target 26% reduction in greenhouse gas emissions by 20% below the business as usual.

2.3. Greenhouse Gas Emission from Garbage Sector

Landfills emit greenhouse gasses directly to the atmosphere[14] due to the decomposition of organic wastes. Greenhouse gasses cause global warming and the risk of an explosion at the landfill. In Indonesia, assuming that no burning garbage at the landfill, CO_2 and CH_4 emission from waste were estimated 1000 Gg and 1600 Gg respectively in 2008.[15] The emission of CH_4 and CO_2 from Jatibarang landfill were estimated 2,611 Gg/yr and 2,886 Gg/yr, respectively in 2020 below the business as usual and it was estimated will increase continuously.[16]

3. MATERIAL AND METHOD

3.1. Physical and Chemical of MSW Characterization

The physical characteristics of MSW include waste composition fraction, moisture content, and fixed carbon in dry weight fraction. The method of collecting and measuring the sample of MSW used SNI 19-39644994[17] and ASTM D 5231-92 (2003).[18] The MSW was classified into 12 nine combustible waste categories: rubber waste, absorbent hygiene product waste, styrofoam waste, plastics waste, rubber waste, textile waste, wood waste, yard wastes, kitchen waste, coco waste, and miscellaneous combustible waste. The dry weight was calculated by

$$\text{dry weight } (\%) = \text{wet weight } (\%) * (100 - \text{moisture } (\%)) \quad (1)$$

3.2. Heating Value

The heating value determines how much fuel is required incinerator for energy recovery purposes. The heating value, which are the lower heating value (LHV) and the higher heating value (HHV). HHV is concerned when the entire water combustion products in liquid form while the LHV is achieved when all the water of combustion in the form of steam. These values be measured in the laboratory using bomb calorimeter.

3.3. Electric Energy Generation Potential

The energy recovery potential (ERP) in dry basis,[19]

$$\text{ERP}\left(\frac{\text{MWh}}{\text{day}}\right) = \text{dry MSW}\left(\frac{\text{tons}}{\text{day}}\right) \times \frac{\text{LHV}_{\text{db}}(\text{kWh/kg})}{3600} \quad (2)$$

The electric power generation potential (P_{GPE}) can be generated,

$$P_{\text{NPE}} = \eta P_{\text{GPE}} \quad (3)$$

where P_{NPE} is power net generation potential and η is gross efficiency of RDF incinerator power plant.

4. RESULTS AND DISCUSSION

Figure 1 shows the average combustible fraction physical composition in the wet basis of MSW in Semarang city. The MSW contents was styrofoam, rubber, wood, HD plastics, textile, miscellaneous combustible, absorbent hygiene product, paper, coco waste, yard, plastics, organics in increase order were 0.305%, 0.523%, 0.989%, 1.426%, 1.464%, 1.481%, 1.953%, 2.752%, 3.069%, 4.324%, 7.338%, 74.376%. As most developing countries, the MSW was dominated by organic waste. The composition of MSW depends on a number of factors such as the lifestyles

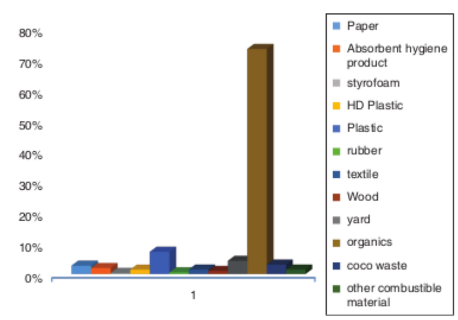

Fig. 1. The MSW composition of Jatibarang land.

Table I. Average composition elemental and proximate analyse of MSW.

Ultimate		Proximate	
Component	% adb	Component	% adb
C	42.43	M	4.33
H	7.62	FC	10.52
N	2.12	VM	75.77
S	0.42	Ash	9.37
O	38.06	HHV	17,744 kJ/kg

Table II. Calculated of MSW composition elemental in wet basis.

Component	Mass fraction
Moisture	45 %
C	19.67
H	3.53
N	0.98
S	0.19
O	24.26
Ash	15

of the population, the relative standards of living, general consumer patterns, and the level of technological advancement of a particular country.

The Chemical characteristics of the municipal solid waste in Semarang are given in Table I. After calculation,[19] the chemical characteristics was given in Table II. The actual moisture content of fresh MSW was 60 to 78% in rainy season and 36%–49% in a dry season. The high average moisture content of the MSW was making incineration a challenging task.[20] MSW can be burnt, without the use of additional fuels, when its LHV exceeds 5–7 GJ/Mg.[11] Diagram Tanner[10, 21] represented a zone of self-combustion is identified for moisture content lower than 50% in mass, ash content less than 60% of mass, and combustibles higher than 25% of mass are showed in Figure 2.

Based on Tanner diagram, the moisture must be below 50%. Thus it is necessary pre-treatment first to decrease the moisture content. After pretreatment, for 45% moisture content and 15% ash, the average LHV of Semarang MSW was 5558 kJ/kg on

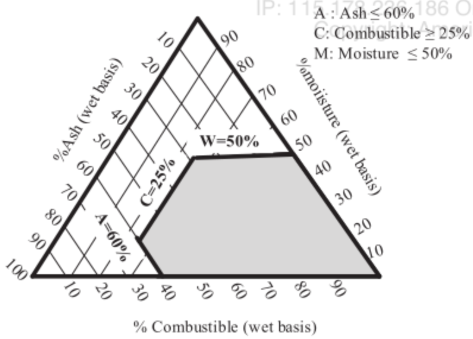

Fig. 2. Tanner diagram.

the wet basis. The C content is still below 25% in mass. The average of LHV db was 9263 kJ/kg. Wet MSW production was 700 tons/day or 450 tons/day dry waste. The energy recovery potential (ERP) in dry basis is 1158 MWh/day. Assuming that the efficiency of an RDF incineration plant was 18%, electric power net generation potential was 8.685 MW. It was nearly 1.14% of the gross Semarang energy consumption where the electricity consumption was 761.112 MW in 2014.[22]

5. CONCLUSION

MSW in Jatibarang with 45% moisture content can be used as fuel.The preliminary results showed that it was possible to recover MSW as a source of renewable energy.

Acknowledgments: This work supported by the Minister of Research and Technology and Higher Education under Grant No. 17/UN7.5.1/PG/2015.

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Received: 12 October 2016. Accepted: 2 November 2016.

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