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ScienceDirect

Energy Procedia 79 (2015) 119 – 124

Energy Procedia

2015 International Conference on Alternative Energy in Developing Countries and Emerging Economies

Sustainable Development and Eco-friendly Waste Disposal Technology for the Local Community

Somrat Kerdsuwan[a,*], Krongkaew Laohalidanond[a], Woranuch Jangsawang[b]

[a]The Waste Incineration Research Center, Department of Mechanical and Aerospace Engineering, Faculty of Engineering, King Mongkut's University of Technology North Bangkok, Bangkok,10800, Thailand
[b]Sustainable Energy Research Center, Faculty of Industrial Technology, Phranakhon Rajabhat University, Bangkok, Thailand

Abstract

With the lack of a management budget and weak policy for waste management of local communities in developing countries, especially for clusters that have the amount of garbage less than 5 tons per day, open dumping or open burning is the most common municipal solid waste (MSW) management, leading to severe impact on the environment. This study focuses on the sustainable development and eco-friendly waste management concept for these local communities. First, public participation campaigns with the 3R's concept (Reduced, Reuse and Recycle) must be launched to reduce and separate waste from households to be mixed with combustible waste, organic waste, and recycled waste. If the separation at the source is successful, the treated waste of about 2.5 tons is divided into wet and dry fractions. The wet fraction can be easily treated by conventional composting to produce soil conditioners and generate income for communities. The dry fraction must be treated by an incinerator. However, due to the high moisture content and low heating value of the waste, the incinerator needs to run with additional fossil fuel, causing high operating costs. Therefore, a novel hybrid incineration-gasification system has been introduced in this study to use Refuse Derived Fuel (RDF) prepared by dry fraction as feedstock to a downdraft gasifier. The producer gas generated from the gasifier can be used to substitute fossil fuel. This sustainable and eco-friendly model of waste management can be used as a prototype model for other rural areas in low or low-middle income countries.

Peer-review under responsibility of the Organizing Committee of 2015 AEDCEE

Keywords: *Municipal solid waste; Sustainable development; Low income countries; Novel hybrid incineration-gasification*

* Corresponding author. Tel.: +0-662-555-2000; fax: +0-662-555-2000.
E-mail address: srk@kmutnb.ac.th.

Peer-review under responsibility of the Organizing Committee of 2015 AEDCEE
doi:10.1016/j.egypro.2015.11.493

1. Introduction

Because of the exponential growth in the world population and the improvement in living standards, the amount of Municipal Solid Waste (MSW), which is the residue from routine human routine activities generated from residential areas and commercial sectors, is continuously increasing. The proliferation of MSW worldwide causes environmental problems, particularly in developing countries or low-income countries where the governmental budget is scant. Although landfilling is the main MSW disposal method worldwide in developed and developing countries [1, 2], the utilization of sanitary landfill has tended to decline in developed countries due to the scarcity of landfill sites and the public's environmental concerns. In contrast to developed countries, many rural areas in developing countries are still using non-sanitary and uncontrolled landfill [1], in this case open dumping, as the MSW disposal method, which leads to negative effects on the environment and human health.

There are two main factors which are still a challenge for MSW management in developing countries: the MSW characteristics and the regulations for MSW management. Compared to MSW generated in developed countries, which contains less than 20-30%-wt. of organic waste, the MSW produced in developing countries has a high organic content of more than 60%-wt. [2, 3]. This high portion of organic waste results in extreme moisture content and low heating value. Considering the regulations for MSW management, most developing countries do not separate any sort of MSW but mix everything together in garbage bags. On the other hand, the regulation for MSW separation has already be in force in developed countries [3]. These two key factors play an important role in the decision making for MSW disposal technology in developing countries.

This study focuses on sustainable development and eco-friendly waste disposal technology for local communities with MSW generation of less than 5 tons per day in developing countries. The Local Administrative Organization (LAO), which generates approximately 5 tons per day MSW, is the representative in this case study.

2. Case Study Area

This study chose Maiked, which is a small district (Local Administrative Organization: LAO) situated 9 kilometers from the city of Prachinburi province in central Thailand, as a representative of an LAO generating less than 5 tons per day MSW. Maiked has an area of 32,650 sq. km. There are 11,417 inhabitants in 3,720 households.

3. Methodology

3.1. Waste characterization

Approximately 1 m^3 of waste at the dumpsite was taken as a sample for determining the physical and chemical composition. The physical composition of the waste, which is the main criteria for selecting the appropriate technology, was investigated using the quartering method and type separation. The physical and chemical properties which are necessary for the design of the selected technology were determined according to American Society for Testing and Materials (ASTM) [4].

3.2 MSW disposal technology

In order to select the appropriate MSW disposal technology for the LAO, approximately 120 questionnaires were given to people from 12 villages there. Furthermore, 4 main criteria were taken into consideration for selection the proper technology, as in the following [5]:

- Practicability and performance, including efficiency, reliability, safety, operator-skill and environmental impact
- Economics, including investment and operation costs
- Maturity of technology
- Technological self-reliance, describing the potential of technology implementation and developing locally

After the technology selection, the process description and mass balance for the whole process was conducted.

Results and Discussion

4.1 MSW characterization

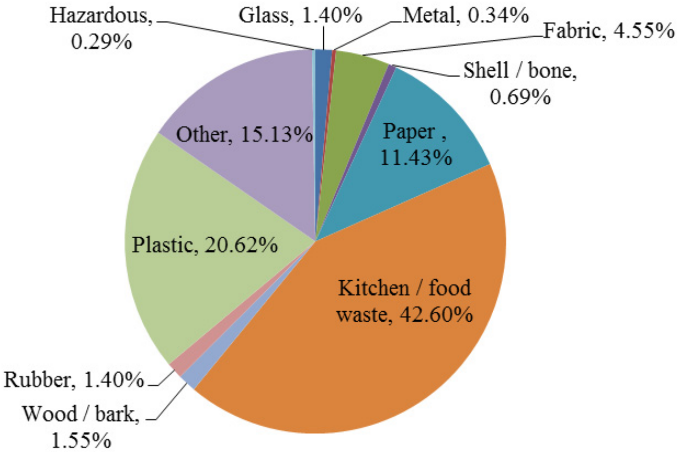

Fig. 1. Physical composition of MSW in Maiked

Table 1. Chemical composition of MSW in Maiked

Properties	Wet fraction	Dry fraction
	Proximate analysis (%-*wt. dry basis*)	
Moisture[1]	73.47	49.23
Volatile matter	74.65	83.94
Fixed carbon	4.17	7.08
Ash	21.18	8.98
	Ultimate analysis (%-*wt. dry basis*)	
Carbon	37.3	49.96
Hydrogen	4.92	7.9
Nitrogen	1.16	0.49
Oxygen	35.22	35.31
Sulfur	0.22	0.07
Chlorine	0	6.27
	Heating value (*kJ/kg dry basis*)	
Higher heating value	15,256	25,945

[1] As received basis

Similar to other rural areas in developing countries, the MSW generated in Maiked had a high percentage of organics waste (wet fraction), e.g. kitchen waste and yard waste, which amounted to 44.2 %-wt. of the total. The remaining was a dry fraction, comprising plastic, paper, cloth, rubber and trace amounts of non-combustible material, e.g. glass, metal and hazardous waste. The physical composition of MSW is presented in Fig. 1. For the chemical composition, the wet and dry fractions were separately analyzed and the results are listed in Table 1.

The volatile matter and the fixed carbon of wet fraction were lower than those of the dry fraction, since it contained no plastic or paper, whereas the moisture content and fixed carbon were higher than those of the dry fraction because of the presence of kitchen and food waste. The high moisture content, low volatile matter, low fixed carbon and high ash content resulted in low heating value compared to the dry fraction. The dry fraction contained a very high amount of chlorine as a result of the presence of plastic waste.

4.2 Appropriate MSW disposal technology

The MSW management model was separated into two cases in this study according the capability of the community to separate MSW into recycled waste, organic waste, and dry-combustible waste, as in the following:

- Case 1: the MSW could not be separated and all of the MSW was treated as mixed waste
- Case 2: the MSW could be separated with a separation efficiency of 25%

For case 1, all of the MSW was treated as mixed waste and Mechanical and Biological Treatment (MBT) was chosen as the appropriate disposal technology. The conceptual design was discussed in the previous work [8]. This paper presents the conceptual design and mass balance for case 2, according to which the MSW can be separated with a separation efficiency of 25%.

Based on the current situation of MSW collection, only 2.5 tons per day of separated MSW were collected and transferred to the disposal site belonging to the LAO. The conceptual design was preliminarily conducted for 2.5 tons per day of MSW. If 25% of the organic waste and 25% of recycled waste can be separated from all of the waste, the recycled waste can be sold at the recycling center, while the organic waste can be treated as wet fraction and the remaining treated with the dry-combustible waste as dry fraction. It was assumed that the hazardous waste was completely sorted out.

Considering the selection criterion mentioned in section 3.2, composting was the appropriate technology for wet fraction (organic waste) disposal since it is widely used and reliable, with no difficulty in operation. Based on viewpoint of economics, this technology requires low investment and operational costs. Additionally, it can be operated in the community households.

Regarding the remainder from the separation process, which was referred to as the dry fraction, incineration was selected as the promising and ultimate technology to treat the dry waste since it can effectively reduce the volume of the mixed MSW, which has high flexibility for a non-homogeneous composition. This incineration technology has been commercially used on both small and large scales in many countries. However, this technology requires energy, normally from fossil fuel, for the combustion process in order to maintain the desired operating temperature; consequently, there are high operation costs. Hence, it is suggested that gasification technology be used in combination with incineration technology to produce producer gas, which can further be supplied in the incineration system as substitute fuel for fossil fuel. The conceptual design of the overall process for the MSW disposal technology, focusing on the incineration technology for dry waste, is illustrated in Fig. 2.

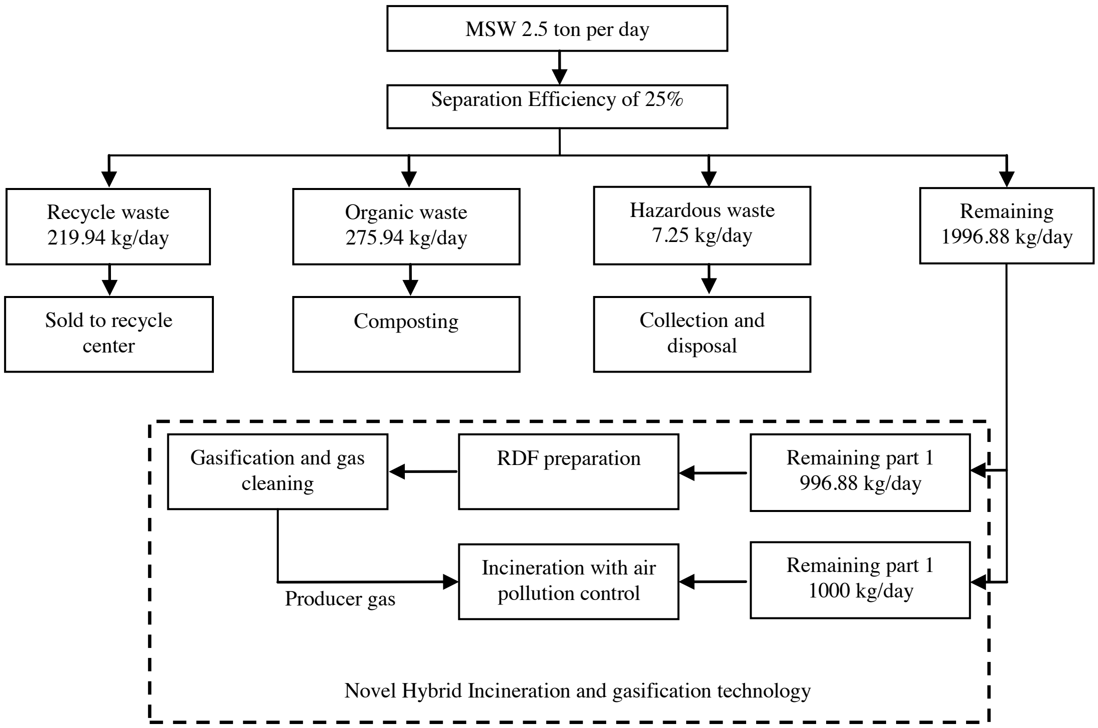

Fig. 2. Conceptual design of the overall process for MSW disposal technology focusing on the novel hybrid incineration and gasification technology

Emphasizing the incineration and gasification technology, the remaining waste was separated into two parts. The first part was used as feedstock for Refuse Derived Fuel (RDF) production and finally served as feedstock for a 50 kg/hr downdraft gasification system. The producer gas obtained from the gasification process was designed to be used as substitute fuel in the controlled air incinerator. The incinerator was designed to have a capacity of 100 kg/hr.

4.3 Economic Analysis

The investment and operation costs of composting technology were estimated to be 5,700 US$ and 600 US$ per year, respectively. The investment cost included land costs and miscellaneous expenses, while the operation costs covered all operating expenses and labour. The incineration and gasification technology had an investment cost of 93,000 US$ covering the RDF preparation unit, the downdraft gasification unit, and the controlled air incineration unit. The operation and maintenance cost was calculated to be 5,405 US$ per year, which included operating expenses, labour, and other expenses. As soil-conditioning/fertilizer is a product of composting, it can be sold. According to the conceptual design, 25 tons per year of soil-conditioning/fertilizer can be produced, which equals the revenue of 1,700 US$ per year. If the LAO invest in composting technology, the revenue will cover all expenses for 5.5 years (payback period of 5.5 years). In contrast to incineration and gasification technology, which has high investment and operation costs, with no revenue except for tipping fees, if the LAO borrows money for investing in this technology, the LAO will see a return on expenses in 14 years, with a tipping fee of 17 US$ per ton. However, this tipping fee is too much for the local community, and therefore it is suggested that the LAO ask for financial support from the government to invest in the technology. In this case, the tipping fee can be reduced to 7.7 US$ per ton.

4. Conclusion

The growth in the population and urbanization has led to an increase in the amount of MSW generation. Since the developing countries or low-income countries do not have a sufficient government budget, non-sanitary and uncontrolled landfill is normally used as the MSW disposal method, which leads to negative effects on the environment and human health. One of the promising methods of MSW management is to reduce the amount of MSW by MSW separation. However, the regulations for MSW separation in developing countries are not as strict as those in developed countries; each LAO should promote MSW separation activities in the community. For the local community with less than 5 tons per day MSW, the MSW to be disposed accounts for approximately 2.5 tons per day after effective MSW. The proper technology for the disposal of MSW in a rural area is controlled air incineration integrated with downdraft gasification. This combined technology has a dominant advantage in terms of reducing operation costs. The producer gas obtained from the gasification process can be used as a substitute for fossil fuel in the controlled air incinerator. The central government should support the LAO in terms of financial funds in order to invest in the necessary technology because MSW management is the responsibility of the government.

Acknowledgements

The authors would like to thank the National Research Council of Thailand (NRCT) for its financial support, and the Waste Incineration Research Center (WIRC), as well as the Department of Mechanical and Aerospace Engineering (MAE), Faculty of Engineering, Science and Technology Research Institute, King Mongkut's University of Technology North Bangkok, for their kind support.

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