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Technological Evaluation of Municipal Solid Waste Management System in Indonesia

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Abstract

As developing countries, Indonesia had their municipal solid waste (MSW) production increase due to population growth and its production reached 190,000 metric ton/day in 2014. Selection of appropriate technology is necessary to reduce the waste volume primarily and to utilize waste as the energy source because of the calorific value inside. Three thermal based technologies are available for waste to energy (WtE) which are incineration, conventional air gasification, and plasma gasification. Their feasibility was evaluated environmentally and economically. None of them was environmentally feasible due to greater CO_2 emission than the CO_2 emission standard of Environmental Protection Agency (EPA). However, two of which, conventional air gasification and plasma gasification, were economically feasible.

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Keywords: Municipal solid waste; incineration; gasification; capital investment; CO_2 emission; feasibility study

1. Introduction

Municipal solid waste (MSW) is a term usually applied to a heterogeneous collection of wastes produced in urban areas. Generally, urban wastes can be subdivided into two major components: organic and inorganic. The characteristics and quantity of the solid waste generated in a region is a function of the standard of living in the city or country. Wastes generated in developing countries have a large proportion of organic waste, while the wastes in developed countries are more diversified with relatively larger shares of plastics and paper [1]. For instance, USA, as a developed country produce 24 % organic waste, while EU and Japan, respectively, produces 34% and 40 % organic wastes. As developing country,

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Indonesia produces 60-70 % organic waste [2]. However, the different composition of waste influences the choice of technology and waste management infrastructure.

In order to contribute generously to global concerns like the depletion of fossil fuels, the greenhouse gas effect and global warming, the need to innovate and employ unconventional energy sources using available natural or non-natural resources has become crucial for the future [3,4]. Besides reducing energy consumption by understanding of energy-saving [5], one of the concepts is waste utilization in form of waste to energy (WtE) concept where generated energy is in the form of heat or electricity from waste [6]. There are two options generally to control the MSW number left for disposal to landfill which are biological and thermal treatments. Biological treatment, however, is lower cost for similar waste, but is more difficult to control the bacteria growth and needs more time. Thus, thermal treatment becomes alternative for the huge volume of wastes [6]. There are three options of thermal based WtE of MSW management system, *i.e.*, incineration, air gasification, and plasma gasification [7,8,9]. Basically, incineration is chemical reaction of oxygen (oxidation) with a combustible material. During incineration, the flue gases produced represented the available fuel energy as heat [8]. Gasification, in particular, is the conversion of solid waste to fuel or syngas through gas forming reactions [10]. The result is not a hot flue gas as in the conventional direct combustion of wastes but a hot fuel gas (syngas), containing large amounts of not completely oxidized products that have a calorific value [11,12]. The organic content of the waste is converted mainly to carbon monoxide, hydrogen, and lower amounts of methane [6,8]. On the other hand, through plasma gasification process, the organic fraction is converted into syngas and the inorganic fraction is vitrified into a non-leachable glass-like slag that can be safely disposed of or even reused as construction material after cooling [12,13]. Since the uniqueness of Indonesia's MSW, technological evaluation becomes crucial stage before establishing the real WtE plant.

On average, Indonesian generates 0.76 kg/day of solid waste. Thus, with total population of 253 million in 2014, Indonesia would generate around 190,000 ton/day of MSW which is administratively distributed into 34 provinces and more than 465 municipalities [1]. MSW management is responsibility by municipality (local government). However, MSW management focuses largely on waste collection, treatment (composting) and disposal. Thus, most local authorities prefer open dumping, creating a despondent situation in the landfill site. This way is the easiest but has many disadvantages for health, safety, and environmental threats, such as spreading of disease & foul odors, causing slide down, contaminate the ground water, etc [1]. Considering these facts, thermal based WtE of MSW management system should be considered by local government in Indonesia. In this study, we chose Piyungan landfill (waste disposal facility) in Yogyakarta Province as a case study.

2. Methods

There are three steps to be executed for thermal based WtE of MSW management system, which are: 1). characterizing the waste chemically, 2). setting the process flow diagram, and 3). studying the feasibility of the process economically and environmentally. The data related to the composition such as garden waste, food waste, etc. were supplied by the Office of Public Work, Housing and Energy-Mineral Resources of Yogyakarta. Characterizing the waste chemically means the mixed organic and inorganic waste were represented by one single chemical formula to simplify the calculation of mass balance and energy balance. The moisture content and the weight percentage of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), sulphur (S), and ash was referred to the previous study [14,15]. The sum of specific element mass of all kinds of waste was then converted into mole to gain the mole ratio among all elements. The mole ratio would be the basis to define the index of each element in a single chemical formula of waste ($C_xH_yO_zN_aS_b$).

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