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Environmental aspects of gasification of Korean municipal solid waste in a pilot plant

Tae-Heon Kwak [a,b], Sanjeev Maken [a], Seungmoon Lee [a], Jin-Won Park [a,*], Byoung-ryul Min [a], Young Done Yoo [c]

[a] Energy and Environment Lab, Department of Chemical Engineering, Yonsei University, Shinchon-Dong 134, Seodaemoon-Ku, Seoul, South Korea
[b] Institute of Woojo Envitech, Yeongdeungpo-Gu, Seoul, South Korea
[c] Plant Engineering Centre, Institute of Advanced Engineering, 633-2, Goan-ri, Baegam-myeon, Yongin, Gyeonggi-do, South Korea

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Abstract

Municipal solid waste was gasified in a 3 ton/day capacity pilot plant based on thermoselect process with oxygen at a temperature of around 1200 °C. CO and H_2 content of synthesis gas were about 27–40 and 36–40%, respectively with high heating value 8.0–10.2 MJ/N m^3. Chlorinated compounds like furan, dioxin, and other organics in gaseous and liquid phase were effectively destroyed due to high temperature of high temperature reactor and shock cooling. Exhaust gases were also found to be satisfying the Korean emission standard. Leachable concentration of heavy metals in the vitrified mineral aggregate were much less than the Korean regulatory limit values due to high melting temperature (1600 °C). The vitrified slag of dark brown color was found to be glassy and non-hazardous in nature and seems to have the possibility to be used as natural raw material in cement and construction industry.

Keywords: Thermoselect process; Synthesis gas; Heavy metals

1. Introduction

In recent years, the quantity of municipal solid waste (MSW) has increased significantly in the industrialized and developing countries raising the question of its sustainable disposal management [1,2]. Waste management systems include waste collection and sorting followed by one or more of the following options: recovery of secondary materials, i.e., recycling [3–5], biological treatment of organic waste, i.e., production of marketable compost [6], thermal treatment, i.e., incineration to recover energy in the form of heat and electricity and landfilling [7]. Landfilling of MSW release GHGs [8–10] and volatile organic compounds along with leachable toxic heavy metals to the surrounding environment [11–16]. Over the years, incinerating waste to generate energy has become the most common method of dealing with combustible waste efficiently as it decreases the volume and mass of MSW [17]. But, incineration has drawbacks as well particularly hazardous emissions and harmful process residues [18,19]. Incineration of MSW generates fly and bottom ashes which release leachable toxic heavy metals, dioxin, furans and volatile organic compounds [20–22]. Stringent environmental regulations are being imposed to control the environmental impact of MSW and incinerator residues [23].

Furthermore, the experiences of the waste incineration industry driven in the past by regulatory as well as technical issues may facilitate their commercial potentials outside the common market especially in highly populated developing countries like Korea with scarce landfill sites. The total amount of MSW generated by Korea was 50,763 tonnes per day in the year 2003 [24]. About 4.6 million tonnes of total waste is being incinerated per year that leads to the

* Corresponding author. Tel.: +82 2 364 1807; fax: +82 2 312 6401.
E-mail address: jwpark@yonsei.ac.kr (J.-W. Park).

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generation of a large amount of solid residues including fly ash and bottom ash and also emits hazardous gases to environment [25]. Moreover, thermal waste disposal can no longer be seen as a process for the reduction of the amount of MSW by weight and volume with the disposal of the generated ashes and Air Pollution Control residues on landfill sites or their application in cement and construction industry. Thus, there is a need to consider MSW as a valuable indigenous source of fuel abundant especially in consumer-oriented societies able to substitute fossil fuels in power generation and other industrial processes. Increasing space constraints for landfilling of MSW and public opposition to new incinerators for waste disposal has effectively eliminated this as a future option in many countries.

In recent years, several new technologies which involve gasification or combinations of pyrolysis, combustion and gasification processes are currently being brought into the market for energy efficient, environment friendly and economically sound methods of thermal processing of wastes [26–33].

Recently, Daewoo Engineering and Construction Corporation installed a high temperature recycling pilot plants for waste of any kind with a patented process called thermoselect with the collaboration of THERMOSELECT, Switzerland. The process consists of compression, degassing with fixed bed oxygen blown gasification, and melting of mineral residues [34,35]. In our previous paper, we studied the gasification of municipal solid waste using double inverse diffusion flame burner and double normal diffusion flame burner [36]. The goal of this paper is to study the environmental impact of gasification of Korean MSW in this pilot plant.

2. Pilot plant process description

2.1. Gasification of MSW

MSW collected from Y-city in Korea was used for gasification in 3 ton/day capacity pilot plant. Process flow diagram of gasification process is shown in Fig. 1. In this process, pyrolysis and gasification processes are carried out in a single unit [37,38]. The stages of waste preparation and sorting are eliminated. The wastes are compressed to about one fifth of their initial volume using a hydraulic press in a long canal heated from outside and maintained at temperatures higher than 600 °C. The high degree of compaction greatly reduces the residual air content, nitrogen does not need to be heated and subsequently cleaned, and heat conductivity is significantly improved. Liquids which escape during compaction flow into remaining cavities. The compression enables the canal to be airtight. As wastes move through the canal they are heated, dried and nearly completely pyrolyzed by the time they reach the end of the canal. The products of pyrolysis then enter into the gasification zone called high temperature reactor (HTR) where the materials are gasified with oxygen at a temperature of around 1200 °C. A high quality synthesis gas and a molten

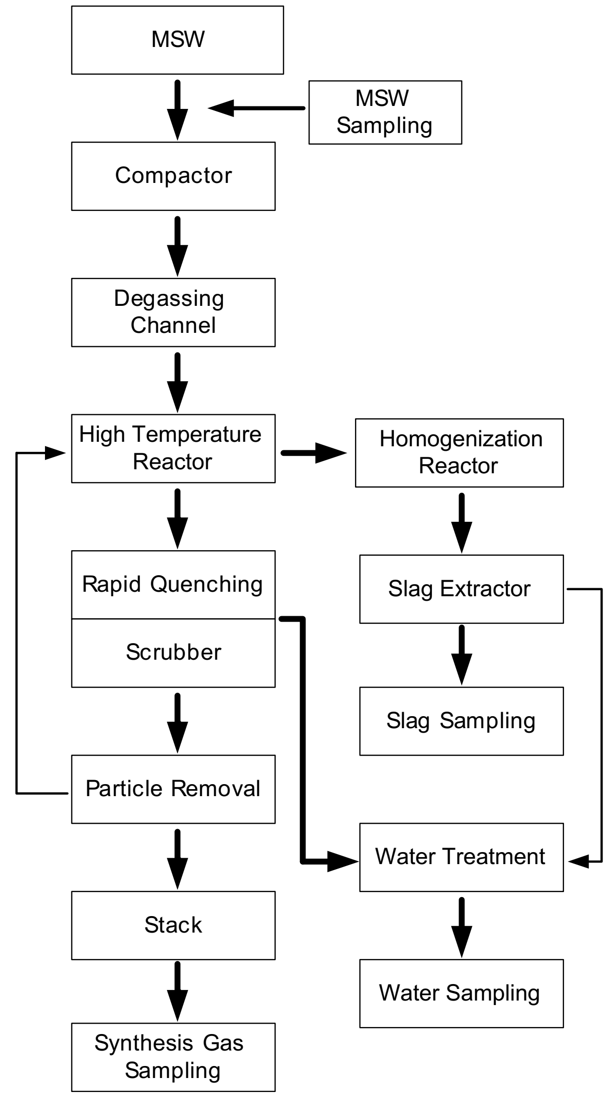

Fig. 1. Block flow diagram for 3 ton/day gasification/melting furnace.

by-product are formed. The gas is rapidly cooled from 1200 °C to 70 °C by spraying water through the gas. This rapid temperature reduction, i.e., shock cooling of gases combined with an absence of available oxygen avoids the reformation of dioxins, furans and other organic compounds from elementary molecules in the syngas due to the de novo synthesis back reactions [39]. Thereafter, cleaned and made available for use either in power generation or as a raw material for chemical processes. The molten by-product flows to the homogenization reactor where, with a supply of oxygen and propane gas, the metal and mineral components of the waste gets smelted at a temperature in excess of 1600 °C ensuring thermal destruction of all chlorinated carbon and stabilization of heavy toxic metals.

2.2. Synthesis gas cleaning

Following the shock cooling, the synthesis gas flows through an acidic scrubber where further HCl and HF