Bioresource Technology 125 (2012) 23–29

Contents lists available at SciVerse ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Urban energy mining from municipal solid waste (MSW) via the enhanced thermo–chemical process by carbon dioxide (CO_2) as a reaction medium

Eilhann E. Kwon [a,b], Marco J. Castaldi [a,*]

[a] Department of Earth and Environmental Engineering [HKSM], Columbia University in the City of New York, New York, NY 10027, United States
[b] Bio-Energy Research Team, Research Institute of Industrial Science and Technology (RIST), 545-090 Kwang Yang City, South Korea

HIGHLIGHTS

- ▶ Thermo–chemical process of municipal solid waste (MSW).
- ▶ Enhanced gasification of MSW by using CO_2 as a reaction medium.
- ▶ Substantial reduction of condensable hydrocarbons (tar) in CO_2 atmosphere.
- ▶ Substantial increase of Syngas under the presence of CO_2.
- ▶ Modification of gasification products under the presence of CO_2.

ARTICLE INFO

Article history:
Received 13 July 2012
Received in revised form 16 August 2012
Accepted 19 August 2012
Available online 31 August 2012

Keywords:
Municipal solid waste (MSW)
Carbon dioxide (CO)
Biomass
Polymer
Thermo–chemical process

ABSTRACT

The enhanced gasification of municipal solid waste (MSW) using carbon dioxide (CO_2) as the gasification medium was investigated to achieve environmentally benign and energy efficient ways for the disposal of MSW. Two main steps of thermal decomposition of MSW were observed. The first thermal degradation step occurs at temperature between 280 and 350 °C and consists of the decomposition of the biomass component into light C_{1-3}-hydrocarbons. The second thermal degradation step occurs between 380 and 450 °C and is mainly attributed to polymer components, such as plastics and rubber, in MSW. To extend this understanding to a more practical level, MSW samples were tested in a drop tube reactor (DTR) at a temperature range from 500 to 1000 °C under various atmospheres with CO_2 concentrations of 0–30%. The release of major chemical species from the DTR has been determined using a micro-GC. For example, CO (~30%), H_2 (~25%) and CH_4 (~10%) were generated.

1. Introduction

Currently, fossil-based energy resources, such as petroleum, coal, and natural gas, are responsible for about 75 percent of the worlds primary energy consumption, each corresponding to 33%, 24%, and 19%, respectively (Stöcker, 2008). Alternatives to fossil-based energy resources are nuclear power (5%), hydropower (6%), and biomass (13%), representing currently about 15% of the worlds primary energy consumption (Soares et al., 2006; Stöcker, 2008). In this era of diminishing petroleum reserves, it is imperative that industrialized society should develop ways to utilize more effectively abundant and renewable MSW to provide new sources of energy and chemical intermediates (Appels et al., 2011).

The tremendous amount of MSW generated worldwide in 2006 was 2.02 billion tons. In 2006, 251 million tons of MSW was generated in the U.S. and 138.2 million tons (55.1% of total generation) was landfilled (EPA, 2006). Landfills are reported as the largest single source of anthropogenic methane emissions in the U.S. accounting for 132 million metric tons of CO_2 equivalent in 2005, which was nearly 2% of total GHG emissions (Kaufman et al., 2008). Thus, there are tremendous economic, social, and environmental factors that justify the research for alternative MSW management options (Choy et al., 2004) that include mass combustion, production and combustion of refused derived fuel (Chang et al., 1998; Dent and Krol, 1990; Ishii et al., 1987), anaerobic digestion (Cho et al., 1995; Kim et al., 2004; Zhang et al., 2007), and thermal processing (Thamavithya and Dutta, 2008; Xiao et al., 2009).

More than 31 million tons (12.4% of total) of MSW were combusted with energy recovery in 2006, which also has significant benefits in reducing the ~75% volume of MSW (Cheung et al., 2007). In addition, gasification technologies (Choy et al., 2004; Jung et al., 2005; Malkow, 2004; Thamavithya and Dutta, 2008; Xiao

* Corresponding author. Address: Department of Earth and Environmental Engineering [HKSM], Columbia University in the City of New York, 400West 120th Street, New York, NY 10027, United States. Tel.: +1 212 854 6390; fax: +1 212 854 7081.
E-mail address: mc2352@columbia.edu (M.J. Castaldi).

0960-8524/$ - see front matter © 2012 Published by Elsevier Ltd.
http://dx.doi.org/10.1016/j.biortech.2012.08.073