Productionof Catalytic and Non-catalytic Gases from Pyrolysis of Municipal Solid Waste (MSW)

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by

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LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
CO_2	Carbon Dioxide
CO	Carbon Monoxide
CCD	Central Composite Design
CFCs	Chlorofluorocarbons
EPA	Environmental Protection Agency
FVT	Flash Vacuum Thermolysis
FFD	Fractional Factorial Design
HC	Hydrocarcbons
LCD	Liquid Crystal Display
MSW	Municipal Solid Waste
MHLG	Ministry of Housing and Local Government
MVT	Mississippi Valley-Type
MnO	Manganese Oxide
MRFs	Materials Recovery Facilities
MHV	Miniature High Voltage
NDIR	Nondispersive Infrared Sensor
NDS	National Design Standard
OBD	On Board Diagnostic
RSM	Response Surface Methodology
SWM	Solid Waste Management
SDD	Silicon Drift Detector

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TON	Turn Over Number
TOF	Turn Over Frequency

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Pengeluaran Gas Katalitik dan Bukan-katalitik daripada Pirolisis Sisa Pepejal Perbandaran (SPP)

ABSTRAK

Sisa pepejal perbandaran (SPP) terutamanya sisa yang dihasilkan oleh isi rumah, dan juga termasuk beberapa sisa perdagangan dan perindustrian yang sama sifat dengan sampah rumah dan telah dilupuskan di tapak pelupusan perbandaran, menyebabkan pelbagai kesan-kesan merbahaya kepada alam sekitar dan manusia. Pada masa kini, kitar semula SPP adalah isu yang penting di kebanyakan negara maju dan membangun seperti di Malaysia juga. Salah satu teknik yang berkesan untuk mengitar semula SPP adalah Pirolisis. Pirolisis adalah degradasi bahan makromolekul dengan haba dalam ketiadaan oksigen. Ia mempunyai kedua-dua aspek gunaan dan analitikal. Pembangunan proses pirolisis pantas maju untuk pengeluaran gas telah mendapat perhatian banyak dalam dekad yang lalu, kerana mereka menawarkan cara yang mudah untuk menukar sisa SPP nilai rendah kepada hasil gas dan produk nilai tambah. Proses pirolisis telah digunakan untuk mengitar semula sisa pepejal perbandaran ke dalam bentuk tenaga yang boleh diperbaharui. Pirolisis lebih berkesan untuk memulih produk dari bahan buangan berbanding pembakaran. Apabila SPP dibakar dalam insinerator moden produk yang praktikal bukan sahaja tenaga, tetapi gas, minyak dan arang pepejal daripada pirolisis juga boleh digunakan sebagai bahan api yan telah melalui proses penulenan dan digunakan sebagai bahan mentah bagi petro-kimia dan aplikasi lain. Di samping itu, pemangkin dalam proses pirolisis ini telah memainkan peranan yang penting untuk meningkatkan hasil keluaran. Walau bagaimanapun, beberapa penemuan telah didapati pada pemangkin dalam proses pirolisis ini. Dalam kajian ini, saya memberi tumpuan kepada pengeluaran gas dari proses pirolisis sisa pepejal perbandaran dengan menggunakan tiga jenis pemangkin (zeolit, dolomit asli dan dolomit dipanaskan). Oleh itu, kajian ini memberi tumpuan kepada gas (HC, CO dan CO_2) analisis daripada pirolisis sisa pepejal perbandaran (SPP) dengan zeolit sebagai pemangkin, empat jenis pengkalsinan(900 ^oC/4h, 700 ^oC/4h, 950 ^oC/3h dan 800 ^oC/5h) dan dolomit semula jadi sebagai pemangkin, dan juga proses pirolisis SPP yang tidak menggunakan pemangkin. Dolomit yang melalui pengkalsinan pada 950 ^oC/3h dan 800 ^oC/5h telah dipilih sebagai pemangkin yang sesuai bagi pengeluaran CO dan CO_2. Dalam projek penyelidikan ini ñcatatestò hiliran tetap - katil reaktor pada julat suhu antara 30 - 750 ^oC telah digunakan dan pengeluaran gas daripada pirolisis SPP berubah-ubah dalam lingkungan 35 - 57mol%. Hasil kajian menunjukkan kehadiran dolomit yang telah melalui proses pengkalsinan mempengaruhi dengan ketara hasil produk dan komposisi gas dalam proses pirolisis, dan inimenunjukkan kehadiran pemangkin penting kepada peningkatan hasil gas dan mengurangkan hasil minyak dan hasil arang berbanding dengan menggunakan zeolite

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sabagai pemangkin dan proses pirolisis yang tidak menggunakan apa-apa pemangkin. Suhu yang lebih tinggi 550 - 750 ^{o}C mengakibatkan penukaran yang SPP ke dalam pengeluaran gas lebih tinggi dengan amat suatu peningkatan CO dan sedikit peningkatan kandungan CO_2. Akibatnya, CO dan CO_2 adalah faktor utama pengeluaran rumah hijau dan bio gas (tenaga). Sementara itu, gas bio daripada pirolisis SPP adalah sangat wajar sebagai bahan mentah untuk proses Fischer - Tropsch atau sintesis untuk pengeluaran bahan api pengangkutan, juga boleh digunakan secara langsung sebagai Nilai Pemanas Sederhana (NPS) bahan api.

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Production of Catalytic and Non-catalytic Gases from Pyrolysis of Municipal Solid Waste (MSW)

ABSTRACT

Municipal Solid Waste (MSW) is primarily waste produced by the household, but also includes some commercial and industrial waste that is similar in nature to household waste and has been deposited in municipal landfill site, causing multitude of harmful impacts to the environment and to human beings. Currently, recycling of MSW is an essential issue in many developed and developing countries like in Malaysia as well. One of the effective techniques for MSW recycling is pyrolysis. Pyrolysis is the degradation of macromolecular materials with heat in the absence of oxygen. It has both applied and analytical aspects. The development of advanced fast pyrolysis process for gas production has gained much attention in the last decade, because they offer a convenient way to convert low value MSW residues into gas yield and value-added products. In this study, pyrolysis process has been used for municipal solid waste recycling into renewable kind of energy. Pyrolysis offer more scope for recovering products from waste than incineration. When MSW is burnt in a modern incinerator the only practical product is energy, whereas the gases, oils and solid char from pyrolysis can be used as a fuel but also purified and used as a feedstock for petro-chemicals and other applications. In addition, catalyst in pyrolysis has been playing significant role to increase product yields. However, a few literatures were found on catalyst in pyrolysis process. This study focused on gas production from pyrolysis process of municipal solid waste by using three types of catalysts (zeolite, raw dolomite and calcined dolomite). Thus, this study focused on gases (HC, CO and CO_2) analysis from pyrolysis of municipal solid waste (MSW) with catalysts zeolite, four types of calcined (700^{o}C/4h, 800^{o}C/5h, 900^{o}C/4h and 950^{o}C/3h) and raw dolomite as catalyst, and also non catalytic pyrolysis of MSW. Calcined dolomite 950^{o}C/3h and 800^{o}C/5h were selected as suitable catalyst among others for CO and CO_2 production. Research project has been investigated in a ñcatatestò downstream fixed ï bed reactor over the temperature range between of 30 ï 750^{o}C. Gas production from pyrolysis of MSW varied in the range of 35 ï 57 mol%. The results indicated the presence of calcined dolomite influenced significantly the product yields and gas composition in pyrolysis process, and revealed essential catalytic performance on increasing gas yield and decreasing oil yield and char yield comparing to zeolite and non ï catalytic pyrolysis process. A higher temperature of 550 ï 750^{o}C resulted in a higher conversion of MSW into gas production with a greatly increasing of CO and slight increasing of CO_2 contents.

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CHAPTER 1

INTRODUCTION

1.1 Background

Municipal Solid Waste (MSW) is primarily waste which is produced by the household, but also includes some commercial and industrial waste that is similar in nature to household waste and has been deposited in municipal landfill sites. MSW can be a liability if requiring disposal but also represents a considerable resource that can be beneficially recovered by the recycling of materials such as aluminum cans, metals, glass, fibers or through recovery operations such as conversion to energy and composting. However, significant quantities of MSW continue to be disposed of in landfill largely due to its low cost and ready availability. Clearly, new waste management practices are needed (Anon, 2003).

In landfill the biodegradable components of MSW (e.g., paper and food wastes) decompose and emit methane ï a greenhouse gas 23 times more potent than carbon dioxide and the cause of significant environmental problems. Other components (e.g., leachate) can also cause significant environmental pollution in air and ground water, and give rise to odour. In general, valuable resources are wasted. For these reasons most countries aim to reduce their dependence on the use of landfills for MSW.

Consequently, MSW is one of the three major environmental problems in Malaysia. It plays a significant role in the ability of nature to sustain life within its capacity.

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Currently, over 23,000 tons of waste is produced each day in Malaysia. However, this amount is expected to rise to 30,000 tons by the year 2020. For instance, 100 ï 150 tons of MSW / day produced by households and also by industrial organizations. 305 tones of MSW / year produced in the state of Perlis. The amount of waste generated continues to increase due to the increasing population and development, and only less than 5% of the waste is being recycled (MHLG, 2003). While the rural population still produces 0.8 kg/cap/day in Malaysia, the main problem seems to be the consumption-oriented urban middle-class that generates about 1.9 kg/cap/day of municipal solid waste (Shy et al., 2009). Approximately in Malaysia, between 70 to 80 percent of municipal solid waste is placed in landfill (Sumiani et al., 2009). For many years landfill was inexpensive and the most common technique for solid waste disposal. Any type of waste simply dumped in an open area of ground without any attempt for recovering or recycling. Despite the massive amount and complexity of waste produced, the standards of waste management in Malaysia are still unstable. These include outdated and poor documentation of waste generation rates and its composition, inefficient storage and collection systems, disposal of municipal wastes with toxic and hazardous waste, indiscriminate disposal or dumping of wastes and inefficient utilization of disposal site space (Sivapalan et al., 2003).

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Recycling municipal waste can be done in several ways, including some alternative ways that have less of a harmful impact on the environment. Environmental recycle advocates point out that the old methods of taking care of municipal waste disposal are not effective, and cause great harm to the environment. Landfills have a large harmful environmental impact, in the form of leachate which can contain harmful metals and

chemical pollutants, and this can get into the groundwater. Landfills also accumulate greenhouse gases, from the decomposition process, which contribute to global warming. There are other alternative methods of municipal waste disposal that can be more eco friendly, and some can be a used for conversion to energy source. Recycling municipal waste can be a source of energy for our home and car (MHLG, 1998).

Pyrolysis is one alternative method for municipal solid waste treatment, and this method offers many benefits. In the pyrolysis process, organic matter thermally decomposes in an environment that is devoid of any oxygen. Gasification is another method for municipal waste disposal, and it follows much the same process as pyrolysis, except that the environment where the decomposition takes place has a small limited amount of oxygen, unlike pyrolysis where the environment has no oxygen. A heat source is required for the pyrolysis process, but no heat source is needed for gasification, because this process is self sustaining thermally. When both pyrolysis and gasification processes occur at the same time, the gasification combustion reactions can provide the heat source needed for the pyrolysis process to perform the reactions. In this process no heat source outside of the gasification process is needed for pyrolysis (Demiral and Sensoz, 2008).

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The products obtained from catalytic pyrolysis process depend on the characteristics of the catalyst used. The different catalysts are characterized by different operating conditions and different product distributions. Catalysis in this context was used mainly to crack higher molecular weight compounds to a lighter and more commercially valuable product gas. Dolomite and zeolite were employed in biomass steam gasiýcation

processes to enhance the yield and quality of product gas and decrease tar yield by cracking and reforming the high molecular weight organic components with steam, the catalytic activity of calcined dolomite were extensively investigated in ýxed - bed reactors (Chaudhari, et al. 2003; Xiao, et al. 2006), but few literatures have been found on catalytic behaviors of calcined dolomite in the pyrolysis of MSW.

In the present work, the purpose of this study is to investigate the possible use of the organic fractions of MSW as an energy resource through a process of pyrolysis in a lab-scale continuously feeding ýxed ï bed reactor with zeolite, natural dolomite and calcined dolomite as catalysts. Nevertheless, non-catalytic pyrolysis of municipal solid waste was also investigated in order to make comparison between catalytic and non-catalytic pyrolysis for gas productivity. The obtained gas production was analyzed and their usabilityôs as potential sources of renewable fuels were investigated.

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1.2 Problem Statement

A limited supply of natural resources combined with an ever growing demand for energy and raw materials has promoted the development of recovering cryptic energy resources from municipal solid waste. In Malaysia, the per capita generation rate of MSW is 0.5 kg/person/day which in the major cities the figures have extended to 1.7 kg/person/day. The existing dumping sites in Malaysia mostly are not properly engineered and managed; pollutant that are released or discharged from the disposal sites finally caused direct and indirect impact to humanôs life.

Harmful gas emission from landfill sites, steady increasing of MSW and in addition lots of energy and money has been used for transportation, treatment, and final disposal of MSW, and thus the disposal of MSW is one of the most essential and urgent problems in environmental treatment in the world because of the decrease in the available space for land filling and the growing concern about the living environment.

On the other hand, less of research investigations being implemented in terms of catalyst dolomite activity for gas yield production in pyrolysis process and also insufficient researches were done on calcinations of dolomite under variety temperature and itôs comparison with other catalysts activity for gas yield production.

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1.2.1 Impacts of Municipal Solid Waste on Health

The group at risk from the unscientific disposal of solid waste include ï the population in areas where there is no proper waste disposal method, especially the pre-school children; waste workers; and workers in facilities producing toxic and infectious material. Other high-risk group includes population living close to a waste dump and those, whose water supply has become contaminated either due to waste dumping or leakage from landfill sites. Uncollected solid waste also increases risk of injury, and infection (HISW, 2007).

In particular, organic domestic waste poses a serious threat, since they ferment, creating conditions favorable to the survival and growth of microbial pathogens. Direct