Renewable and Sustainable Energy Reviews 36 (2014) 107–122

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

An overview of characteristics of municipal solid waste fuel in China: Physical, chemical composition and heating value

Hui Zhou [a], AiHong Meng [a,b], YanQiu Long [a], QingHai Li [a], YanGuo Zhang [a,*]

[a] Key Laboratory for Thermal Science and Power Engineering of Ministry of Education, Department of Thermal Engineering, Tsinghua University, Beijing 100084, PR China
[b] School of Environment, Tsinghua University, Beijing 100084, PR China

ARTICLE INFO

Article history:
Received 26 June 2013
Received in revised form
12 February 2014
Accepted 7 April 2014
Available online 14 May 2014

Keywords:
Municipal solid waste
Physical component
Proximate analysis
Ultimate analysis
Heating value

ABSTRACT

In this paper, the characteristics of physical and chemical composition of municipal solid waste (MSW) in China were reviewed and the statistical indexes, namely mean value, standard deviation, coefficient of variation, and *t*-test, were applied to analyze the physical composition, proximate, ultimate analysis, and heating value. Listed in decreasing sequence, the physical components of Chinese MSW are in food residue, non-combustibles, plastics, paper, textiles, wood waste, and rubber. In food residue, the average elementary hydrogen (H), oxygen (O) and nitrogen (N) content varied greatly with samples and the chlorine (Cl) and moisture contents were extraordinarily high. While conversely, the components of wood waste were simple and different components displayed little disparity in characteristics. The elemental compositions of paper and textiles were also simple. The properties of chlorine-free plastics (polyethylene, polypropylene and polystyrene) were consistent, with high volatile matter, carbon (C) and H content. The mean higher heating value (HHV) of polrvinyl chloride (PVC) was about a half of that of chlorine-free plastics, because the Cl content of PVC was approximate 50%. It suggested that plastics with or without chlorine should be separated as possible. The HHV of different rubbers varied sharply, from 21,812 to 38,868 kJ/kg. A model was proposed to predict the proximate and ultimate analysis and heating value from physical composition, in which the PVC fraction in plastics and the supplementary moisture coefficient were introduced. The results showed that the predicted results fitted well with the measured ones.

Contents

* Corresponding author. Tel.: +86 10 62783373; fax: +86 10 62798047 801.
E-mail address: zhangyg@tsinghua.edu.cn (Y. Zhang).

http://dx.doi.org/10.1016/j.rser.2014.04.024
1364-0321/

1. Introduction and scope

1.1. The generation and management of municipal solid waste in China

China, as a developing country, has the world's largest population of about 1.37 billion according to the population census in 2010. With the rapid development of national economy, the ever-accelerating urbanization and the continuous improvement of residents' living standard, the yield of solid waste, particularly municipal solid waste (MSW), are constantly increasing, reaching 170.81 million tons by 2012 [1]. Annual generation of MSW in China is expected to reach 172 and 200 million tons by 2013 and 2020, respectively. Therefore, proper waste treatment is hence an urgent and important task for the continued development of cities [2].

Incineration is preferred to landfill disposal in MSW treatment [3] due to its decomposition and immobilization of hazardous substances, high-degree volume reduction, low space requirement and effective energy recovery [4]. In China, waste incineration has developed very rapidly since 1980s. The incinerated MSW increased from 3.70 million tons in 2003 to 35.84 million tons in 2012 and the number of incineration plants increased from 47 to 138 [1,5]. In recent years, waste pyrolysis and gasification are also drawing great concern [6]. They represent an alternative process to enhance both the energy and economic value of MSW utilization, as well as to provide products that have potential to be further utilized [7].

1.2. Problems regarding MSW thermal conversion investigations in China

Due to the uniqueness of MSW from other fuels, existing research results attained from studies into other solid fuels (coal, peat, petroleum coke, and biomass) can hardly be applied directly in the field of MSW. In a certain number of investigations into MSW, incomplete scientific approaches or scattered and non-uniform data lead to inaccurate results. To obtain a comprehensive understanding of MSW, the characteristics of MSW and some problems in research into MSW are elucidated in this paper.

(1) The composition of MSW is complicated and is impacted by a number of factors. Not only does MSW composition vary across time and region, disparity among related data provided by different researchers can also be detected [8–18], as shown in Table 1. In 1997, the percentage of food residue in MSW of Qingdao was 42.20%, while that of Xi'an was 15.74%. Even with the same region, the MSW composition also varied across time. For example, food residue made up 85.8% of the waste of Dalian in 1993, while the percentage decreased to 59.86% by 2007; meanwhile, the content of paper, textiles and plastics increased accordingly.

(2) The percentage of moisture and ash contents of different types of MSW shows noteworthy difference, as shown in Table 1. The moisture in MSW of Shanghai in 1998 was 58.87%, while that of Beijing MSW in the same year was 39.31% [21]. Moisture and ash contents influence the heating value (HV) of MSW to a considerable extent. LHV of Dongguan MSW was as high as 8847 kJ/kg, while that of MSW in Wuhu in 1997 was only 2863 kJ/kg: the latter was less than 1/3 of the former. The volatile matter of different MSW varies, as shown in Table 1. The volatile matter of Hong Kong waste as dry base in 1997 was 35.31%, while that of Xi'an in the same year was only 20.03%. The volatile matter impacts the ignition of MSW incineration. The higher volatile matter content, the more easily MSW can be ignited. In pyrolysis and gasification, the volatile matter influences composition and yield of the gas products. Higher the volatile matter content, the more gas pyrolysis and gasification generate. However, previous investigations are normally based on a particular type of waste. Considering the complicatedness of various influential factors that contribute to the disparity of content of MSW, and it is difficult to gain more extensive and representative conclusions.

(3) Due to the complexity of MSW, previous research concentrated on the thermochemical properties of certain types of substance in MSW [42–51]. Nevertheless, for a specific component in MSW, such as plastics, different researchers reported diverse proximate and ultimate analysis results and thermal kinetic parameters [42,43,48,52]. In fact, plastics are not a single component, since it comprises different materials such as polyethylene (PE), polypropylene (PP), polystyrene (PS), and polyvinyl chloride (PVC). Materials have various proximate and ultimate analysis results, as well as thermal kinetic parameters. For instance, the C content of PE is as high as 85.5% [53], while that of PVC was only 34.24% and the Cl content of PVC is 52.21%. Different elemental compositions will lead to different gas products after thermochemical processes. Furthermore, the combustion of materials containing chlorine may produce persistent organic pollutions (POPs) such as polychlorinated dibenzo-*p*-dioxin, polychlorinated dibenzofurans (PCDD/Fs), and polychlorinated biphenyls (PCBs) [54] which are highly toxic and may have carcinogenic and mutagenic effects [55]. However, some ultimate analysis did not detect the Cl content, and even mistook the Cl content for O content, which led to serious errors [45].

(4) The variation of heating value of MSW will greatly impact the stable operation of incinerator. According to engineering experience, to ensure complete combustion, the monthly average LHV of MSW should be more than 4127 kJ/kg [56]. However, HV is seldom reported in detail. Analytical method is important when determining the accuracy and validity of the data. The HV are usually described in terms of HHV, LHV, or bomb heating value (BHV). Although these terms are related,