Powder Technology 278 (2015) 118–129

Contents lists available at ScienceDirect

Powder Technology

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

The separation of the main combustible components of municipal solid waste through a dry step-wise process

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ARTICLE INFO

Article history:
Received 10 October 2014
Received in revised form 29 January 2015
Accepted 11 March 2015
Available online 21 March 2015

Keywords:
Engineered fuel
Municipal waste
Dry separation
Segregation
Fiber
Plastic

ABSTRACT

Tailoring the solid waste-based fuel composition is essential to improve the combustion efficiency and control the resulting emissions. In the present study, a dry step-wise process has been developed in a pilot-scale setup to recover the main combustible elements of shredded bulky waste (SBW) consisting of 72% fiber, 12% soft plastic and 8% hard plastic. For this purpose, the SBW is initially elutriated to enhance the processability of the feedstock and separate its lightest components. Elutriation of SBW at $U_e = 1.5$ m/s for 15 min could result in the effective separation of light components, i.e., fiber and soft plastic. These components are then separated from each other in a second elutriation column at $U_e = 0.2$ m/s for 2–3 min. In the presence of a proper fluidization medium, the non-elutriated fraction of the SBW is further separated into non-combustible, undesirable combustible components and hard plastic through two consecutive steps. Size and density of the bed medium as well as the initial configuration of the bed inventory are the parameters governing the recovery and purity percentage of the fluidization steps.

1. Introduction

The gradual depletion of the fossil fuels has persuaded the world around researchers to explore other reliable energy resources. It is expected that the global energy market will continue to depend on fossil fuels for only another few decades. Coal constitutes approximately 65% of the fossil fuel reserves in the world. Unlike the oil and gas reservoirs, which are concentrated in a few regions of the world, coal is abundant and broadly distributed throughout the world. Economically recoverable reserves of coal are available in more than 70 countries worldwide, and in each major world region. These two geological reasons support the fact that coal reserves have the potential to become the dominant fossil fuel in the future [1]. Coal is projected to have the biggest increase in demand in absolute terms, jumping by 73% between 2005 and 2030. It is the largest source of electricity generation in China and the United States, i.e., 68.7% and 46% of total power generated in these countries, respectively. Coal power plants, however, are the least carbon efficient power stations in terms of the level of carbon dioxide produced per unit of generated electricity [2]. In addition, the combustion of fossil fuels, including coal, contributes to acid rain, global warming, accelerated soil acidification, forest degradation and air pollution due to the impurities and chemical composition of the fuel [3]. Combustion of fossil fuels is the main cause of significant amounts of pollutants, such as NO_x and SO_2. Fig. 1 demonstrates the rate of NO_x and SO_2 emissions of several American coal-based power plants in 2013.

Management of municipal solid waste (MSW) is one of the major issues facing the world [4]. Both landfills and the resulting emission of greenhouse gases (GHG) present serious health and environmental threats.

MSW generally undergoes pre-treatment processes, including metal separation and the removal of other recyclable material: fiber (referred to as paper), plastics, metals and glass. The MSW can be further processed to remove waste with low calorific value (food waste, yard trimmings, rubber, leather, textiles and other waste) and then shredded (in the range of a mesh 4, hole size of approximately 4.75 mm) for the production of fuels. The resulting waste stream, referred to as shredded bulky waste (SBW), is composed of combustible materials (plastic, fiber, wood and others) and small amounts of non-combustible materials (glass, metals, sand and others).

Fig. 2 shows the composition of the total amount (251 million tons) of MSW generated in the United States in 2012. As illustrated, the total percentage of paper, paperboard, and plastic, which are the main combustible materials, reaches 40.1% or the equivalent of 100 million tons. With the current recycling capability of MSW in the United States (about 47%), the potential for SBW production has been 47 million tons in 2012.

Due to its high content in combustible material, the SBW can be incinerated or used as feedstock to produce fuel, such as refuse-derived fuel (RDF), solid recovery fuel (SRF) or other types. The incineration process produces large quantities of GHG, e.g., CO_2. Typically, the

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http://dx.doi.org/10.1016/j.powtec.2015.03.017
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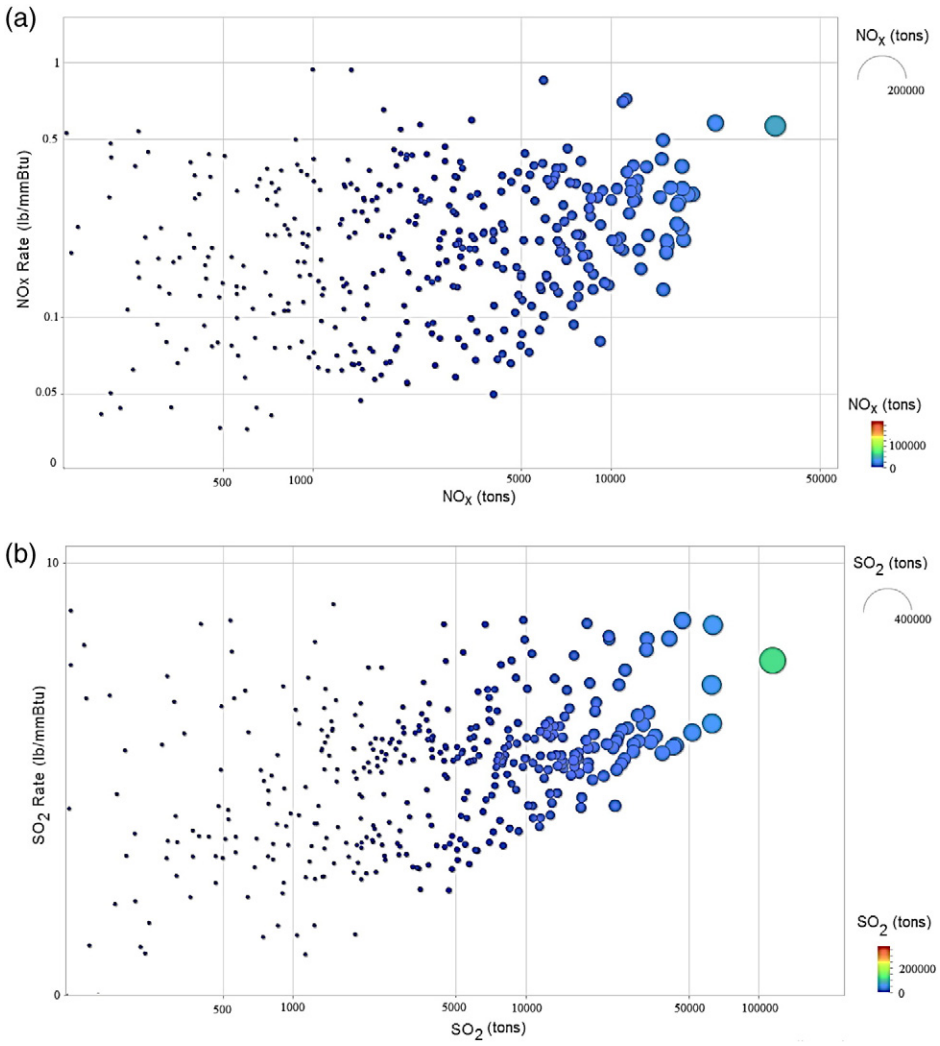

Fig. 1. a) NO_x b) SO_2 emission rate of some of the US power plants combusting coal [5,6].

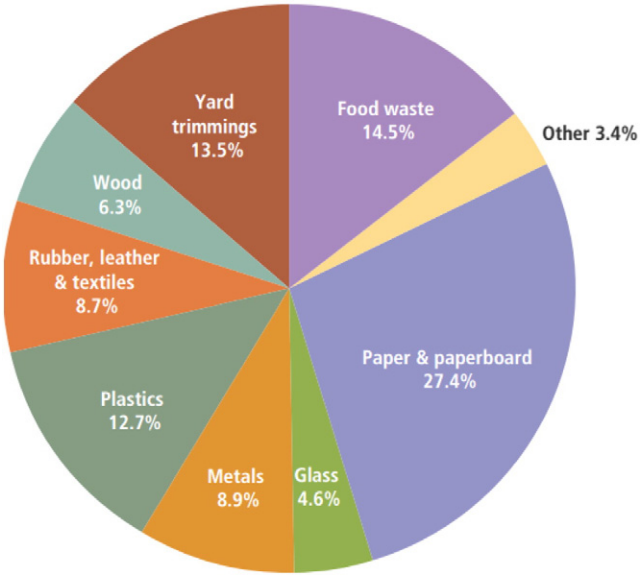

Fig. 2. Total MSW generation (by material), 2012 [7].

amount of energy produced per equivalent CO_2 expelled during incineration is very low, thus incineration of SBW for energy production is one of the worst offenders in producing GHG released into the atmosphere [2].

Typically, RDF refers to the segregated high calorific fraction of processed MSW. The term SRF is used to describe a fuel with tight quality specifications required by the customer [8]. In spite of processing MSW to produce RDF or SRF, the final streams include a variety of different combustible materials whose composition is prone to change due to the alteration of the waste source composition and variation of the MSW processing efficiency. On the other hand, it is vital to control the composition of the solid waste-based fuel in order to avoid technical problems and harmful emissions. For instance, the combustion of waste paper and paperboard leads to the production of a significant ash content, which may disturb combustor operation. In addition, burning chlorine-contained plastics, such as Polyvinyl chloride (PVC), included in hard plastic waste causes serious corrosion in the furnace or kiln [9]; however, the presence of a low level of chlorine may be useful to mitigate mercury emissions by transforming them to mercuric chloride, which is more readily captured either in scrubbers or by collection in the particulate form [10]. In view of these facts, it is crucially important to develop a novel solid waste-based fuel with customized characteristics. Such a fuel, which has been patented as "Engineered Fuel (EF)," aims at offsetting or replacing coal as the feedstock in coal fired power