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Release and Transformation of Potassium during Combustion of Biomass

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Abstract

To investigate the release and transformation of fuel K during combustion of biomass, wheat straw and corn stalk are burnt in a fixed-bed reactor system during 400−1000 °C, and weight measurement, elemental composition analysis, and chemical fractionation analysis are performed. The influences of fuel type, combustion temperature, and water washing pretreatment are discussed. The results show that wheat straw has a higher K release ratio than corn stalk, especially when combustion temperature is above 500 °C. For both biomass fuels, the released K is far less than the water-soluble K. For wheat straw, some of the other occurrence modes of K turn into the insoluble K gradually. For corn stalk, the water-soluble and ion-exchangeable K turn into HCl-soluble and insoluble K. Water washing removes all the water-soluble K of corn stalk and reduces the K release from 3.26 to 0.27 mg g^{-1} at 1000 °C.

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Keywords: Potassium release; Transformation; Biomass combustion; Water washing

1. Introduction

Biomass has been considered to be a good alternative to fossil fuels owing to its short time of regeneration and environmentally friendly characteristics [1, 2]. Sending biomass fuels to boiler for heat and/or power production seems to be a prospective scheme for biomass utilization [1, 2]. In Europe, North America and China, the grate-fired boiler has been widely used for biomass combustion [3]. However, this type of boiler has been experiencing serious

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problems of fouling, slagging and high-temperature corrosion on superheaters [4, 5]. It is believed that these problems are originated from the release of K, Cl and S during biomass combustion. Studying the release and transformation of potassium is of great importance for the design of grate-fired boilers or other thermal conversion equipments.

According to the previous studies [3, 6-10], the release of potassium was usually quantified based on weight measurements and elemental analyses of raw biomass and residual sample. It is acknowledged that the release behaviour of fuel potassium is closely related to its occurrence mode in biomass [3]. However, only limited attention [11] has been focused on the transformation of occurrence mode of fuel potassium during biomass pyrolysis. To our knowledge, such transformation during biomass combustion has not been reported. The pretreatment of biomass fuels by water washing could remove fuel potassium effectively and alleviate potassium-induced problems in the grate-fired boiler [12, 13]. To date, the influence of water washing on the potassium release has not yet been quantitatively evaluated.

In this study, biomass combustion experiments are performed in a fixed-bed reactor system, which is built up to simulate the conditions on the grate of the biomass-fired boiler. The release of fuel potassium is determined quantitatively based on mass balance during combustion of wheat straw and corn stalk in a wide temperature range. The transformation of potassium occurrence mode in raw sample and residue is examined at different temperatures through chemical fractionation analysis. The effects of fuel type, combustion temperature, and water washing pretreatment, are discussed in detail.

2. Materials and Methods

2.1. Sample Preparation

Two biomass fuels, including wheat straw and corn stalk (collected from Xi'an, Shaanxi Province, China), are used for investigation in this study. Washing pretreatment is carried out on the corn stalk, and the details are described in our earlier studies [12, 13]. The corn stalk sample of 12.5 g is submerged and soaked in the deionized water of 1 L with a temperature of 30 °C for 3 h. To obtain the potassium content, biomass sample is directly dissolved by pressurized acidic digestion and then analyzed by inductively coupled plasma spectrometry. All the raw and washed biomass samples are cut and sieved to 150−250 μm. After air-drying at 105 °C for 24 h, samples are sent to the combustion experiment and the chemical fractionation analysis. The fuel properties of biomass samples are presented in Table 1 [13].

Table 1. Proximate and ultimate analyses, and composition of main ash-forming elements of raw and washed biomass samples.

	Wheat straw	Corn stalk	Washed corn stalk	Standard deviation
Proximate analysis (wt %, dry basis)				
Ash	6.80	7.09	4.32	0.07
Volatile matter	75.29	74.89	80.95	0.28
Fixed carbon	17.91	18.02	14.74	0.31
Ultimate analysis (wt %, dry basis)				
C	44.11	46.18	46.54	0.18
H	4.97	4.89	5.10	0.05
O	43.67	40.50	43.44	0.23
N	0.20	1.09	0.57	0.03
S	0.25	0.25	0.02	0.02
Cl	0.183	0.055	0.024	0.004