

The study of characteristics through biomass burning

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Abstract. As a major agricultural province in China, Northeast China produces a lot of biomass while its grain yield is high. Open burning is an efficient and convenient way to remove biomass. However, air pollutants (PM_{2.5}, CO, VOCs) will be released in the process of biomass combustion, which will have a certain impact on Regional Environmental quality, atmospheric visibility and human health. Because of the various type of biomass, their combustion products and effects are different. In this study, there collected peanut hull, rice husk, straw and wood particles, and carried out the simulated combustion experiment in the laboratory environment simulation chamber. The inorganic elements, water-soluble ions and speciation analysis of combustion products were determined. The results showed that the content of Zn was higher than that of carcinogenic element in the eight inorganic elements after combustion. The water-soluble ion emission factors of wheat straw and wood particles are larger than those of peanut hull and rice husk, and the water-soluble ions are mainly K⁺ and Cl⁻. Through the morphology analysis of combustion products, it can be seen that different types of biomass have different morphology after combustion, which are mainly strip, column and particle. Combined with energy spectrum analysis, it is found that the content of K and Cl is high. The results lay a theoretical foundation for the study of local biomass combustion and provide data for the determination of local biomass combustion emission characteristics.

1 Introduction

Typical biomass combustion mainly includes four types: forest fire, open-air burning of agricultural straw, burning of wood and straw as agricultural fuel [1]. Biomass combustion will release air pollutants including PM_{2.5}, Co, VOCs and so on, which will have a certain degree of impact on regional environmental quality, atmospheric visibility, human health and climate change [2,3]. In recent years, different scholars have carried out research on biomass open-air combustion at different scales, including forest fires in Southeast Asia [4], North America [5] and Africa [6]. However, as a large agricultural country in the world, a large amount of straw is produced in the process of grain planting, and its open burning and indoor fuel consumption are the main forms of biomass combustion in China [7], and most of them are concentrated in Northeast China, North China Plain and Yangtze River Delta region [8]. In particular, Northeast China, as the main grain producing area in China, produces a large amount of biomass in the process of agricultural production. However, it is located in the northern cold area, and the plant growth period is relatively short. Open burning is the most efficient way to clean up the land [9]. According to research, about 20-30% of agricultural biomass is burned in the open air during the grain harvest season [10].

In previous studies, satellite remote sensing images and statistical data were mostly used to study the impact of biomass open-air combustion at different scales, such as regional, national and global [11]. However, there are few studies based on local biomass incineration. This limitation is mainly due to the variety of biomass and different combustion characteristics [12], so it is necessary to carry out combustion characteristics of different types of biomass in order to provide more accurate data support for the determination of local biomass combustion emissions and emission factors.

In this study, four biomass types including peanut hull, rice husk, straw and wood particles were selected. After testing and analyzing their basic physical and chemical properties, PM_{2.5} particles were collected and incinerated in the laboratory environment chamber. The inorganic elements and ionic components of PM_{2.5} particles were collected and incinerated. At the same time, scanning electron microscope (SEM) was used to analyze the combustion products and particulate matters of different biomass the results lay a theoretical foundation for the study of local biomass combustion characteristics, and provide data support for the determination of local biomass combustion emission characteristics.

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2 Materials and methods

2.1 Biomass sample collection

In this study, four types of biomass were selected: peanut hull, rice husk, straw and wood particles. They were collected in the rural areas around Changchun during the grain harvest season. In the process of collection, 1m×1m sampling points were selected and collected at the diagonal. During the collection process, the samples were cut and collected with ceramic scissors. Three samples were evenly collected and loaded to the sealed bag, record the sampling time, location and other data, and take it to the laboratory for determination of water content, volatile matter, calorific value and other physical and chemical properties (Table 1). The surplus samples are placed in -40 °C ultra-low temperature refrigerator for further experimental test.

2.2 Determination of inorganic elements in biomass combustion samples and PM_{2.5} samples

In daily life, biomass is often removed by outdoor field combustion, but the combustion conditions are not easy to control, and the flue gas is difficult to collect after diffusion, so this study adopts the method of Simulated Combustion in laboratory environment chamber. 5g peanut husk, rice husk, wheat straw and wood particles were respectively weighed and placed on the tray covered with tin foil.

In the disk, the combustion simulation was carried out in the environment simulation bin with the size of 1m³. Before the experiment, the exhaust air of the simulation bin was opened, and the exhaust valve was closed after exhaust for 3h. When the biomass began to burn, the flue gas PM_{2.5} was collected with the sampling flow rate of 30 L / min and the sampling time of 30 L / min Whatman quartz filter membrane was selected as the sampling membrane. The filter membrane was weighed before and after sampling and placed in the ultra-low temperature refrigerator for testing.

Take 1/4 of the above PM_{2.5} filter membrane samples, cut them into small pieces with ceramic scissors, put them in the microwave digestion container, add 20ml nitric acid hydrochloric acid mixed digestion solution, immerse the filter membrane fragments in it, cover them, put them in the digestion tank assembly, screw them tightly, and put them on the microwave turntable frame. The digestion temperature was set at 200 °C and the digestion duration was 15min. after digestion, the digestion tank components were taken out and cooled. The inner wall of the microwave digestion container was washed with water, and about 10ml water was added, and the digestion was carried out for 0.5h. Filter the extract into a 50ml volumetric flask and fix the volume with water to 50 ml scale. When the content of organic matter is too high,

appropriate amount of hydrogen peroxide can be added to decompose organic matter during digestion.

According to the standard of "determination of metal elements in air and exhaust gas particles by inductively coupled plasma atomic emission spectrometry" (HJ777-2015), the contents of eight heavy metals including Cu, Pb, Mn, Cr, Cd, Zn, As and Ni in biomass straw combustion and PM_{2.5} were quantitatively analyzed by ICP-OES.

2.3 Ion composition analysis of biomass combustion samples

Take 1/4 of the above PM_{2.5} filter membrane sample, cut into small pieces with ceramic scissors and put into the sample bottle, add 100ml. Na⁺, K⁺, F⁻, Cl⁻, NO₃⁻ and SO₄²⁻ were determined in this study.

2.4 Morphology analysis of biomass combustion samples

Field emission scanning electron microscopy (FESEM) combined with energy dispersive spectrometer (EDS) was used to analyze the microstructure and morphology of straw after combustion. Before the SEM/EDS test, the filter membrane was cut and dissected properly, and the basic tissue was observed under the electron microscope.

3 Results and discussions

3.1 Emission characteristics of heavy metals after biomass combustion

It can be seen from table 1 that the emission factors of Cu, Pb, Mn, Cr, Cd, Zn and Ni in PM_{2.5} from five kinds of biomass straw combustion flue gas are in the range of 2.15-901.99 µg/kg. The emission factors of Zn particles are 525.58, 901.99, 397.76 and 592.72, in peanut hull, rice husk, wheat straw and wood, respectively. The emission factors of Cr, Pb and Cu are higher, while As and Mn are lower.

It is also known from the table that the emission factors of the same heavy metals vary with different biomass types. The Zn emission factor of rice husk is higher than that of the other three biomasses and is relatively similar peanut hull and wood particles. Among the eight heavy metals, the emission factors of carcinogenic heavy metals (Ni, As, Cd, Pb) are relatively low, among which the emission factors of As are the lowest. The emission factors of As in wheat straw and wood particles are 1/4 and 1/20 of peanut hull and rice husk, respectively. It shows that although the open burning of biomass will have different degrees of impact on the atmospheric environment quality, the emission of carcinogenic substances is relatively low.

Table1. Physicochemical properties of biomass and analysis of heavy metals after combustion

	Peanut husk	Rice husk	Wheat straw	Wood particles
Moisture (%)	10.3	8	15.5	9
Volatile (%)	66.4	64	64.38	75.7

Calorific value (kcal/kg)	3453.822	3762.19	2867.92	3855.89
Cr (µg/ kg)	33.24	15.16	21.09	37.20
Mn (µg/ kg)	22.25	13.33	14.37	21.80
Ni (µg/ kg)	8.01	13.70	13.83	10.83
Cu (µg/ kg)	25.71	21.68	38.60	9.11
Zn (µg/ kg)	525.58	901.99	397.76	592.72
As (µg/ kg)	9.11	42.43	2.15	2.94
Cd (µg/ kg)	13.80	17.50	21.41	17.56
Pb (µg/ kg)	22.70	16.79	25.04	33.06

3.2 Analysis of ion composition after biomass combustion

The water-soluble ion components of peanut hull, rice husk, wheat straw and wood particles are mainly shown in Table 2. The water-soluble ion emission factors of different biomass are in the range of 10.29-168.17 mg/kg. K^+ and Cl^- are the two inorganic water-soluble ions with the largest emission factors of biomass combustion. The emission factor of SO_4^{2-} is next to K^+ and Cl^- and the lowest is NO_3^- . The results showed that the K^+ emission factor of wheat straw (131.75 mg/kg) was the largest, which was 1.65 times of peanut straw (79.73 mg/kg), and the Cl^- emission factor of wood particles (168.17 mg/kg) was 1.47 times of rice husk (114.37 mg/kg), indicating that the four biomass emitted more K^+ and Cl^- , which accounted for 65.85%-74.69% in the total water-soluble ions. The results showed that the content of K^+ and Cl^-

from straw combustion was the highest in water-soluble ions, and previous studies [13] showed that the concentration of K^+ and Cl^- in urban atmosphere increased significantly during straw burning, which was consistent with the results of this study.

On the whole, the water-soluble ions emitted by wheat straw and wood particles were 390.85 mg/kg and 392.9 mg/kg, respectively, which were higher than those of peanut hull and rice husk (300.75 mg/kg, 310.88 mg/kg), respectively. Therefore, compared with the other two biomasses, the combustion of peanut hull and rice husk contributed more. The emission factors of F^- , NO_3^- , SO_4^{2-} and Na^+ are relatively low in six water-soluble ions. Relevant studies show that they mainly come from fluoride plants, vehicle exhaust, smelting plants, sea salt and so on [14,15]. While K^+ mainly comes from biomass combustion [16], and Cl^- is related to coal combustion and biomass combustion [17,18]. Therefore, it can be seen that biomass combustion has an inapparent impact on F^- , NO_3^- , SO_4^{2-} and Na^+ , and has an obvious impact on K^+ and Cl^- .

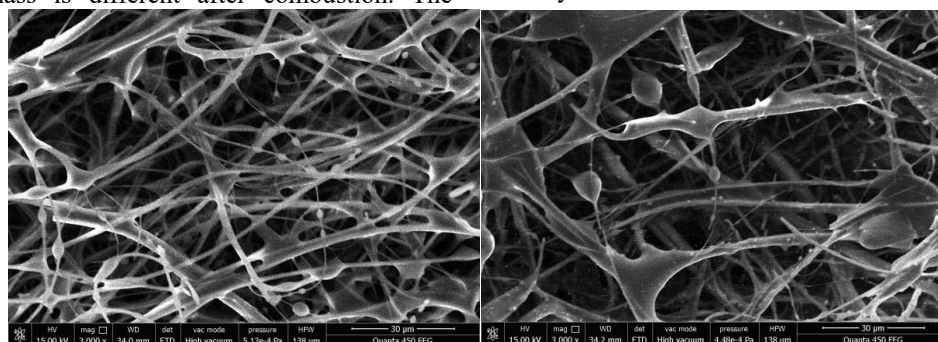
Table2. Analysis of ion composition after biomass combustion

	Peanut husk	Rice husk	Wheat straw	Wood particles
K^+ (mg/kg)	79.73	99.39	131.75	114.35
Na^+ (mg/kg)	24.95	27.74	31.14	25.25
F^- (mg/kg)	17.19	14.59	22.50	18.37
Cl^- (mg/kg)	118.31	114.37	160.17	168.17
NO_3^- (mg/kg)	10.46	10.29	10.82	17.14
SO_4^{2-} (mg/kg)	50.11	44.50	34.47	49.62

3.3 Morphology analysis of biomass after combustion

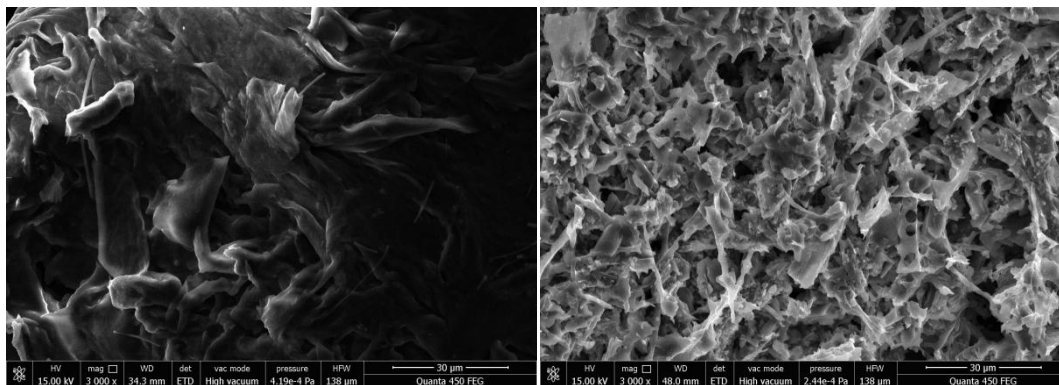
The following figure shows the SEM pictures of the basic organization of the combustion products of different biomass. It can be seen that the morphology of the four types of biomass is different after combustion. The

morphology of wheat straw and rice husk is mainly long strip, while the morphology of peanut shell is mainly columnar particles. The morphology of wood particles can be seen in both strip and column shape, and spherical particles of different sizes are attached on the surface. The results show that there are obvious protuberant particles on the surface, showing a high content of inorganic salts. Analysis shows that the content of K and Cl is high.



(a). Wheat straw

(b). rice husk



(c). Peanut shell

(d). wood particles

4 Conclusions

In this study, four different types of biomass including peanut hull, rice husk, wheat straw and wood particles were selected. The simulated combustion experiment was carried out in an indoor closed environment chamber. The inorganic elements, ion composition and morphology of smoke and dust after different types of biomass combustion were determined. The conclusion is as follows:

(1) The results showed that the content of Zn was higher than that of carcinogenic element in the eight inorganic elements.

(2) The results show that the content of CL in anions is higher than that in cations.

(3) Scanning electron microscopy (SEM) was used to observe the morphology of combustion products of four kinds of biomass. It can be seen that there are different shapes such as strip and column. Combined with energy spectrum analysis, the contents of K and Cl in the products are relatively high.

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