学位論文内容の要旨

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学位論文題名

Methodology for reducing particulate matter emissions during combustion by improving fuel quality of low-grade biomass

（低品位バイオマスの燃料品質改善による燃焼時の微粒子状物質排出低減化のための方法論）

The ever-increasing energy demand will lead to more exploitation of fossil fuels and subsequent emission of greenhouse gases into the atmosphere. Instead, carbon-neutral biomasses can be utilized as alternate solid fuels. Although it has the potential to substitute fossil fuels, low energy density and particulate matter (PM) like pollutants' emission during combustion makes it an unpopular alternative. Given that PM emission is one of the leading causes of 4 million premature deaths by household air pollution each year, it is an urgent issue that must be addressed. Hence, increasing energy density and reducing PM emissions is essential to utilize biomasses as a renewable fuel source and to alleviate health issues caused by household air pollution.

1. Effect of ash content and combustion temperature on reduced particulate matter emission by biomass carbonization

Thermochemical pre-treatments, including carbonization, have been suggested as an effective method to valorize biomass. One of the key features of carbonization is the enrichment of fixed carbon (FC), and reduction of volatile matter (VM) of biomass fuel by producing energy-dense biochar. The produced biochar is expected to reduce PM emissions during combustion due to the reduction of VM. However, the benefits of carbonization, particularly PM reduction, might not be equal for all types of biomasses because of composition heterogeneity and differences in combustion conditions. Therefore, an assessment of PM emission reduction by carbonization of various types of biomasses at different combustion temperatures is required. In this study, seven different

types of biomasses (larch, poplar, miscanthus, bamboo grass, rice straw, rice husk, and dairy manure) and their biochars (prepared at 400 °C) were combusted at 650, 750, and 850 °C. As a result of carbonization, recovery of carbon was greater than 50% for all biomasses except dairy manure, and PM emissions were reduced by as much as 95.5%. It implies the potential of carbonization for biomass fuel quality improvement. PM reduction was significant at low combustion temperatures for all feedstocks. Although the combustion temperatures did not strongly affect PM emissions from low-ash (≤6.7%) biomass, higher heating temperatures (≥750 °C) stimulated PM emissions from ash-rich rice straw and dairy manure biochar. Therefore, to limit PM emissions from the chars produced by high ash biomass, a lower combustion temperature is preferable.

2. Reduction of PM emission from high-ash biochar

A considerable amount of PM can be emitted during the combustion of biochars that are produced from low-grade biomass (LGB), even after a significant amount of VM was reduced by the carbonization process. We hypothesize that mineral transformation occurs in high-ash biochar during the combustion at higher temperatures and that releases as PM. Therefore, in this study, the emission factor of high ash-containing biochar was investigated at combustion temperatures between 650 to 850 °C. The PM emission from these biochar samples was increased with the increase in combustion temperature. The composition of minerals in the ashes of rice straw, rice husk, and dairy manure was investigated before and after heating at different temperatures (650, 750, and 850 °C). Mineral analysis revealed that enhanced PM emission from ash-rich biochar samples can be attributed to a greater concentration of Na and K and the melting of their compounds at higher combustion temperatures. We also found that co-combustion of low-ash biochar with high alkali-containing biochar may effectively reduce the PM emission, mainly by the mineral dilution mechanism. Considering the suggested approaches to reducing PM emissions, further research is required to develop field utilization of biochar as a solid fuel product.