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学位論文紹介
Doctoral Thesis Introduction

Development of Elemental Technologies for Utilization of Biomass Combustion Ash as Fertilizer

バイオマス燃焼灰の肥料化に向けた要素技術の開発

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1. Introduction

Biomass combustion ash has a potential to be applied as fertilizer since it contains K_2O which is an essentials macro-nutrient for plants and low level of heavy metals. However, its direct utilization is limited by the presence of unburned carbon content and the low content of soluble potassium. Therefore, developing efficient methods to separate unburned carbon and to increase the soluble-potassium content is crucial for enhancing the value of biomass combustion ash for fertilizer application.

2. Separation of unburned carbon by using tilted sidewall louver classifier

A novel louver classifier geometry with tilted sidewall was used to separate the unburned carbon (UC) from biomass combustion ash. Based on CFD simulation, the tilted sidewall in the louver classifier increased the downward velocity in the classification region, led to increase the separation performance. Based on the experimental result, this novel-modified louver classifier increased the reduction of unburned carbon (RUC) in ash up to 83.8%. The RUC increased with a cut size of classified ash which was achieved when a high inlet flow velocity and high blow-up ratio are applied. The lowest UC content achieved in this study by using novel louver classifier geometry was under 5%LOI (Loss on Ignition), meet the criteria for soil and agricultural use.

3. Water- and citric acid soluble potassium

The classification methods in the two types of woody biomass combustion fly ash revealed that the potassium concentration increased as the median diameter decreased. The potassium components could be present as finer particles or as cover over coarser particles composed of crystalline SiO_2. Differences in the existence forms of the potassium components caused differences in the dependence of potassium concentration on the median diameter. The water and citric acid soluble potassium concentration of the classified ash in which their potassium existed as finer ash particles exceed the commercial standard for fast- and slow- release potassium fertilizer.

Moreover, the enhancement of soluble potassium content in biomass combustion fly ash was investigated by transforming insoluble potassium into soluble forms through heat treatment on insoluble potassium at 700–950°C by kaolin addition. The presence of kaolin effectively hindered formation of the less soluble crystalline phase of K_2SiO_3, instead facilitating the production of cubic leucite, a more soluble form of potassium in citric acid. This treatment improved the potassium solubility in citric acid from 12.2 to 17.9 mg/g.

Furthermore, the value of biomass combustion ash as fertilizer can be fully realized when its combustion ash deposited in the bottom of cyclone classifier called bottom ash can also be used, in addition to fly ash. As the bottom ash has less dependence of soluble potassium on its median diameter, it could be assumed that the potassium components of bottom ash present as cover over coarser ash particles. The pulverization and classification have successfully improved the surface of ash particles to recover potassium and silicon elements simultaneously from woody biomass bottom ash. By controlling the operation conditions of these methods, the finer particles containing potassium abundantly has separated from the surface of larger particles containing silicon component via surface grinding, resulting the ash particles that have a higher recovery of acid-soluble potassium from silicon components. These findings highlight the versatility of the elemental technologies for utilization of biomass combustion ash as fertilizer.

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List of Publications

[1] F. A. Prasetya, S. Ishizuka, T. Fukasawa, T. Ishigami, K. Sakemi, T. Fukuda, K. Fukui, Influence of ash species on particle size dependence of water- and citric-acid-soluble potassium concentrations of woody biomass combustion ashes with low potassium content, J. Energy Inst. 111 (2023) 101396.

[2] F. A. Prasetya, T. Fukasawa, T. Ishigami, K. Fukui, Classification performance analysis of a louver classifier with a tilted sidewall and its application to the separation of unburned carbon from biomass combustion ash, Sep. Purif. Technol. 355 (2025) 129778.

[3] F. A. Prasetya, S. Ishizuka, T. Fukasawa, T. Ishigami, K. Sakemi, T. Fukuda, K. Fukui, Simultaneous recovery of acid-soluble potassium and silicon components from biomass combustion bottom ash using pulverization methods, Adv. Powder Technol. 36 (2025) 105021.

[4] F. A. Prasetya, S. Ishizuka, T. Fukasawa, T. Ishigami, K. Sakemi, T. Fukuda, K. Fukui, Water- and citric acid-solubilization of potassium components in biomass combustion ash by kaolin addition, Fuel 404 (2026) 136419.

Curriculum Vitae

Fandi Angga Prasetya received his B.Sc and M.Sc in Physics from Institut Teknologi Sepuluh Nopember (ITS), Indonesia, in 2013 and 2014, respectively. He received Dr. Eng in Chemical Engineering from Hiroshima University in 2025. Since 2015 until present, he is a lecturer in Chemical Engineering Department, Universitas Internasional Semen Indonesia.