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Characteristics and Chemical Composition of Fly Ash From Pulang Pisau's Power Plant as A Potential Material for Synthesis of Aluminosilicate Materials

Karakteristik dan Komposisi Kimia Abu Layang PLTU Pulang Pisau Sebagai Bahan Baku Potensial untuk Sintesis Material Aluminosilikat

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ABSTRACT

The Steam-Electric Power Station (PLTU) is one of the initiatives to meet the nation's current electricity requirements. The use of fuel for steam power plant is still dominated by fossil fuels such as coal. Even though domestic energy needs are met, steam power plant turns out to be a contributor to gas emissions that cause global warming, as well as a by-product in the form of fly ash which can cause environmental and ecosystem problems. Fly ash contains silica oxide (SiO_2) and aluminum oxide (Al_2O_3) compounds which can be used as raw materials for synthesizing aluminosilicate-based materials such as geopolymers and zeolites. This study tested the characteristics and composition of chemical compounds in fly ash from Pulang Pisau's power plant, Central Kalimantan. Characterization using X-Ray Diffraction (XRD) showed that peaks of quartz material dominated fly ash from Pulang Pisau's power plant at 2θ=20.82°;26.61° and mullite minerals at 2θ= 31.2°;33.1°; 35.4°;39.2°;59.8°. The results of the chemical compound composition were tested using the ASTM-D3682-12 standard. Fly ash has a composition of 29.00% SiO_2, 9.98% Al_2O_3, 13.75% Fe_2O_3, and 28.37% CaO. Fly ash from Pulang Pisau's power plant is classified as type C fly ash, which can potentially be used as a source of aluminosilicate-based material synthesis.

Keywords: PLTU, fly ash, aluminosilicate.

ABSTRAK

Pembangkit Listrik Tenaga Uap (PLTU) merupakan salah satu upaya untuk memenuhi kebutuhan listrik dalam negeri saat ini. Pemakaian bahan bakar untuk PLTU masih didominasi oleh bahan bakar fosil seperti batu bara. Batu bara merupakan sumber energi yang menjadi bahan bakar utama untuk sumber listrik di Indonesia. Meskipun kebutuhan energi dalam negeri terpenuhi, ternyata Pembangkit Listrik Tenaga Uap (PLTU) merupakan salah satu tempat kontribusi penyumbang emisi gas yang menyebabkan pemanasan global, serta produk samping yakni abu layang (fly ash) yang menimbulkan permasalahan bagi lingkungan dan ekosistem. Abu layang mengandung senyawa silika oksida (SiO_2) dan aluminium oksida (Al_2O_3) yang dapat digunakan sebagai bahan baku sintesis material berbasis aluminosilikat seperti geopolimer, zeolit dan lain-lain. Pada penelitian ini, dilakukan pengujian karakteristik dan komposisi senyawa kimia pada abu layang PLTU Pulang Pisau Kalimantan Tengah. Berdasarkan karakterisasi menggunakan X-Ray Diffraction (XRD) menunjukkan bahwa abu layang PLTU Pulang Pisau didominasi oleh puncak material kuarsa pada 2θ=20,82°;26,61° dan mineral mullite pada 2θ= 31,2°;33,1°;35,4°;39,2°;59,8°. Hasil komposisi senyawa kimia di uji dengan menggunakan standar ASTM-D3682-12. Berdasarkan data yang diperoleh pengujian komposisi kimia abu layang memiliki

komposisi senyawa SiO_2; Al_2O_3; Fe_2O_3; CaO tertinggi dengan persentase masing-masing 29,00%;9,98%;13,75%; 28,37%. Berdasarkan komposisi senyawa kimia, abu layang PLTU Pulang Pisau diklasifikasikan sebagai abu layang tipe C. Dari data tersebut dapat disimpulkan bahwa, abu layang dari PLTU Pulang Pisau sangat berpotensi untuk digunakan sebagai sumber sintesis material berbasis aluminosilikat.

Kata Kunci: PLTU, abu layang, aluminosilikat.

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1. INTRODUCTION

As the global population is expected to rise, so will the yearly energy demand. One of the most critical energy demands is the domestic supply of electrical energy. According to PLN's 2020 Statistical Data, PLN's total production is 274,852.18 GWh, an increase of 14.205 from the previous year (PLN Statistics, 2020). Numerous power plants are utilized to meet demands for electrical energy. Steam-Electric Power Station (PLTU) is one of them. There are 127 PLTU in Indonesia, which is expected to increase annually in parallel with population growth.

Steam power plant produces electricity using coal-based raw materials (Rasyid et al., 2017). Coal is a fossil fuel in the form of sedimentary rock with burning properties formed due to the deposition of organic matter, especially plants. Coal is composed of dominant chemical elements in the form of carbon (C), hydrogen (H) and oxygen (O) (Surahman et al., 2020). Steam power plant have an advantage over other power plants due to the relatively abundant availability of coal in Indonesia. In general, Indonesia's coal type has low calories, so it is less attractive to the export market. In addition to having a positive impact on fulfilling the domestic electricity supply, steam power plant has a negative impact in the form of dangerous fly ash.

Steam power plant contributes to emitting fly ash waste generated from the coal combustion process. Fly ash is a hazardous material that, when disposed into the environment, will cause serious environmental problems, especially in living ecosystems (Sutarno et al., 2019). Fly ash contains heavy metals which will negatively impact the environment, such as reducing soil fertility and polluting waters. In addition to impacting the environment, fly ash can disrupt the health system of living things that are exposed to irritation of the eyes, nose, throat, respiratory system disorders, and nervous disorders that can reduce the ability of the brain system (Sulistiyani, 2016).

Based on previous research, it was reported that fly ash contains oxide compounds such as silicon oxide (SiO_2), aluminium oxide (Al_2O_3), calcium oxide (CaO), and iron oxide (Fe_2O_3) (Abidin & Leksono, 2021). This high content of silicon oxide and aluminium oxide has the potential to be used as the raw material for the production of aluminosilicate-based materials such as geopolymers and zeolites.

Geopolymer is an inorganic polymer material that is synthesized geochemically. Geopolymer is formed due to the polymerization reaction between silica (Si) elements and Aluminum (Al). Geopolymers are getting higher attention because of their advantages such as hard material properties, weather resistance, good thermal stability, porosity, and good compressive strength (Oktaviastuti & Yurnalisdel, 2020). Zerfu et al. (2016) stated that the quality of geopolymer material depends on the type of fly ash and the coal combustion process. Quality geopolymers contain 70% (wt%) total silicon oxide, aluminium oxide, and iron oxide (Zerfu & Ekaputri, 2016).

Zeolite is an aluminosilicate-based material with a very regular structure, high porosity, and good thermal stability properties. Zeolites can be produced from natural materials such as clay, bagasse, kaolin, and lateritic soils (Sukmaladewi, 2017; Iqbal et al., 2018; Endang et al., 2019). In addition to natural zeolites, many synthetic zeolites have been developed, of which there are more than 215 frameworks. Synthetic zeolites that have been identified include the NaY zeolite (Rachman et al., 2018), Y zeolite (Rahayu et al., 2019), and

the ZSM-5 zeolite (Hartanto et al., 2018). Fly ash, which is rich in silica and alumina, has the potential to be used as a raw material in the production of zeolite. Therefore, in this study, the chemical characteristics of fly ash obtained from the steam power plant in Central Kalimantan will be studied to determine the chemical composition and characteristics of fly ash crystals as a raw material for synthesizing aluminosilicate materials.

2. MATERIALS AND METHODS

2.1. Materials

The material used was fly ash taken from the Pulang Pisau's power plant Central Kalimantan, which was analyzed using the ASTM-D3682-12 standard. The tool used was X-Ray Diffraction (XRD) (Rhigaku Miniflex600).

2.2. Methods

The fly ash studied was obtained from the Central Kalimantan steam power plant located in the Pulang Pisau Regency area. The fly ash was characterized using X-Ray Diffraction (XRD). Analysis of the fly ash's chemical composition using a method that met the standards according to ASTM-D3682-12.

3. RESULTS AND DISCUSSION

Fly ash was characterized using the X-ray diffraction method to determine the constituent material. The diffractogram in Fig. 1 gives the diffraction pattern at an angle of 2θ. Based on the characterization test using X-Ray Diffraction (XRD), the fly ash of the Pulang Pisau's power plant was dominated by peaks of quartz material at 2θ=20.82°;26.61 and mullite minerals at 2θ= 31.2°;33.1°;35,4°;39,2°;59,8°. Sunarti and Nazudin (2021) stated that the X-ray diffraction pattern of quartz and mullite materials in fly ash indicated the presence of Si and Al elements. The higher intensity of the quartz peaks, when compared to the mullite peaks' intensity, indicates that the silica content in fly ash is higher than that of alumina and other oxides. Based on this high silica and alumina composition, fly ash has the potential to be developed as a raw material for aluminosilicate-based materials such as geopolymers and zeolites.

The chemical composition of fly ash depends on the type of coal being burned. The chemical composition of fly ash from Pulang Pisau's power plant is presented in Table 1. The composition of chemical compounds was tested using the ASTM-D3682-12 standard. The chemical composition of fly ash was 29.00% SiO_2, 9.98% Al_2O_3, 13.75% Fe_2O_3, and 28.37% CaO. The high percentage of SiO_2, Al_2O_3, Fe_2O_3, and CaO will potentially be used as raw materials for the synthesis of aluminosilicate-based materials.

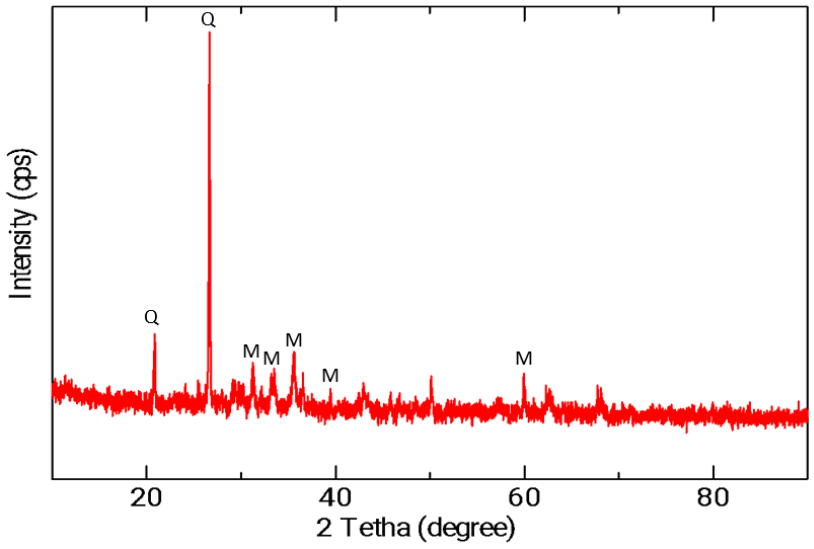

Figure 1. Fly Ash XRD Diffractogram Pattern from Pulang Pisau's Power Plant

Table 1. Chemical Compound Composition of Fly Ash from Pulang Pisau's Power Plant

Chemical Compound	Percentage
SiO_2	29.00
Al_2O_3	9.98
Fe_2O_3	13.75
CaO	28.37
MgO	9.03
SO_3	5.82
P_2O_5	0.32
Na_2O	0.67
K_2O	0.71
TiO_2	1.16
MnO_2	0.28

*Source: original processed data

The type of fly ash influences the quality of aluminosilicate-based materials. Fly ash is generally classified into two types based on its chemical composition (type C and F). Based on the American Society for Testing Material (ASTM) C618 standard, fly ash type F contains more than 70% (wt%) SiO_2, Al_2O_3, and Fe_2O_3 and less than 20% CaO. Type C fly ash contains less than 70% wt% SiO_2, Al_2O_3, and Fe_2O_3 and a CaO content of more than 10% (Hidayati et al., 2020). Based on the ASTM C618 standard, the fly ash from the Pulang Pisau's power plant can be categorized as type C. Table 2 illustrates the classification of fly ash classes from various steam power plants.

Previous research by Wattimena et al. (2017) reported that geopolymers synthesized with high calcium content would have high compressive characteristics. Over time, apart from the geopolymerization reaction, a hydration reaction will occur. Based on this fact, the fly ash of the Pulang Pisau's power plant, which is classified as type C with a very high CaO content, is suitable as a raw material for the synthesis of geopolymer materials. In contrast to zeolite materials, the calcium content in fly ash will affect the crystallinity of the zeolite during the synthesis process. Zeolite synthesized with type C fly ash will produce a residue characteristic of quartz, whereas when the zeolite is synthesized with type C fly ash, it will produce residues of quartz and mullite. Hence, the zeolite synthesized from type C fly ash will have a higher crystallinity than the zeolite synthesized from type F fly ash (Kunecki et al., 2020). Therefore, fly ash from Pulang Pisau's power plant with high CaO content is suitable as raw material for zeolite synthesis.

Table 2. Classification of Fly Ash Class from Various Steam Power Plant in Indonesia

Source of Fly Ash	Classification	Reference
Pacitan Power Plant	Type F	
Semen Gresik	Type C	
Petrokimia Gresik	Type F	Sari et al., 2018
Abu Layang PT. IPMOMI	Type F	
Pulang Pisau's Power Plant	Type C	Results of this study

4. CONCLUSIONS

The characteristics of fly ash will affect the quality of fly ash used as a raw material for synthesizing aluminosilicate materials. Peaks of quartz and mullite material dominate the characteristics of fly ash based on the XRD test. Based on the ASTM C618 standard, the fly ash of the Pulang Pisau's power plant is classified as type C, which is very suitable as a raw material for the synthesis of aluminosilicate materials such as geopolymers and zeolites.

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