The preliminary study of waste ash of Mpanau steam power plant (Mpanau PLTU)

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Abstract. Coal Steam Power Plan is nowadays very important because it serves electricity in certain areas in Indonesia. Mpanau Coal Steam Power Plan (Mpanau PLTU) located at Palu (Central Sulawesi, Indonesia) which is a source of electricity for the people who live in Palu and its surrounding area. The energy source of PLTU derived from coal which is a fossil fuel. The use of coal as an energy source creates some environmental problems such as the ash waste (bottom ash and fly ash). Characterization of waste ash from fly ash and bottom ash in qualitatively and quantitatively ways is the first step to evaluate the environmental impacts related to environmental and biological contamination risk. In this research, silica concentration (SiO$_2$) has been determined after separation method by extraction of both ashes from Mpanau PLTU. Silica concentration of bottom ash and fly ash sample was 21.31% and 29.85% respectively. Furthermore, the extraction silica was characterized by using Fourier Transmission Infra-Red (FTIR), X-Ray Diffraction (XRD), and Scanning Electronic Microscope (SEM) to see morphology.

1. Introduction

Most of the electrical energy sources in Palu and its surrounding areas come from the Mpanau Coal Steam Power Plant (Mpanau PLTU). The energy source used to generate electricity comes from coal which is a fossil fuel. Economically, coal is a cheap and affordable, however, it is a non-renewable. Besides, the use of coal has an impact on environmental damage. This is because coal combustion waste generates solid waste in the form of ash derived from fly ash and bottom ash.

Based on Government Regulation (PP) No. 85 the year 1999 on the management of hazardous and toxic wastes, fly ash and bottom ash from coal combustion is categorized as hazardous and toxic waste. This is because the fly ash and bottom ash contain heavy metal oxides that can naturally pollute the environment which the fatal thing is to damage the survival of various living things (humans, animals, and plants). Based on the observation result of the researchers at Mpanau PLTU, the rest of the coal combustion results in waste ash derived from fly ash and bottom ash and they are only stacked at several points of location around the steam power plant. In addition, it can be seen that a lot of coal-burning ash is found on the roofs of people's houses and on the plants around the location of PLTU. Based on these conditions, this power plant will produce the amount of waste ash that increasing day by day.

Characterization of ash waste qualitatively and quantitatively is the first step to evaluate environmental impacts related to environmental and biological contamination risks [1]. In line with the advancement of science and technology (IPTEK), it allows the management of ash waste into non-
hazardous materials and can be a valuable material as economically. To make this happen, it is necessary that certain treatments be separated the ash from toxic materials and will be safely used as materials to be developed into products of economic value.

Based on the information that has been mentioned above, it is necessary to do research on the preliminary study of what content is contained in ash waste of coal combustion in Mpanau PLTU. However, in this study, only silica (SiO$_2$) compounds will be studied.

2. Methods

Fly ash and bottom ash were picked from several points at Mpanau PLTA. Then, all sample was put in the container.

2.1. Extraction

All samples were homogenized, each type of ash (fly ash and bottom ash), 50 grams soaked in hot water for 2 hours. Then the ash was separated again from the water. Then each sample was weighed again. Each of samples type, 20 grams was immersed in 100 mL 2.5 M NaOH solution then heated to 85°C while stirring with a magnetic stirrer for 1 hour. Subsequently, the sample was filtered and the filtrate containing dissolved silica was placed in a beaker. To precipitate silica, into the filtrate was added 1 M HCl solution gradually until the formation of the silica precipitate stops (pH range 6.5-7). After that, the precipitate was separated and washed with hot water to remove the excess acid. The silica obtained from this treatment was then dried in an oven at 110 °C for 6 hours [2][3]. The yield obtained was measured by silica.

2.2. Characterization

Samples containing silica from the extraction process above were further characterized using Fourier Transform Infra-red Spectrophotometry (FTIR-Shimadzu®-Prestige 21), X-ray diffraclometer (XRD-RigakuSmartLab®), and scanning electron microscope-energy dispersive x-ray spectrometer (SEM-EDS JEOL model 6510).

3. Result and Discussion

The waste ash of Mpanau PLTU used in this research was derived from bottom ash and fly ash which is coal ash. Bottom ash and fly ash are coal combustion products. The number of these two types of ash will increase frequently with wider using of coal. Characteristics of coal ash produced depend on coal type and size also combustion technology. Fly ash and bottom ash are solid waste generated from coal burning at power plants. They have many elements and chemical compounds, one of the largest components is silica. Silica can be obtained from both ash by many separation ways. The silica separation method from ashes in this research was obtained by the simple solid-liquid extraction method.

The solid-liquid extraction is an extraction process involving two phases of a solid phase (ashes) and liquid phase (NaOH). In this extraction, when the extraction material was mixed with the extractant then the extractant will react with the solid material by forming the extract. The silica present in bottom ash and fly ash (figure 1) was obtained by dissolving each of the two types of ash into an alkaline solution, then heated. The purpose of heating to speed up the reaction rate, where high temperatures will increase the amount of soluble silica in the extractant.

![Figure 1. A sample of bottom and fly ash](image-url)
In silica, the high electronegativity of element O causes Si to be more electropositive and create an unstable intermediate [SiO$_2$OH]. In this situation, dehydrogenation will occur and the second hydroxyl ion will bind to hydrogen, here will form water. Two Na$^+$ ions will balance the negative charge formed and interact with the SiO$_2$$^-$$^2$ ions—thus forming sodium silicate [4]. The purpose of stirring at the time of heating is to distribute the temperature to evenly and accelerate the contact between the solvent and the solute. In addition, to reduce the precipitation [5]. The reaction mechanism between SiO$_2$ derived from bottom ash and fly ash with alkali (NaOH) can be seen below:

$$\text{SiO}_2 (s) + 2 \text{NaOH (aq) } \rightarrow \text{Na}_2\text{SiO}_3 (aq) + \text{H}_2\text{O (aq)} \quad (1)$$

Silica can react with a base, especially a strong base in this case NaOH solvent. However, the silica compounds that are formed and still in the form of sodium silicate. Therefore, it is necessary to add 1 M HCl to bind sodium to obtain SiO$_2$. This is in line with what expressed by Kalapathy [6] that the silica compound is easily soluble in an alkaline atmosphere and will settle in an acidic atmosphere. Reaction mechanism can be seen below:

$$\text{Na}_2\text{SiO}_3 (aq) + 2 \text{HCl (aq)} \rightarrow \text{H}_2\text{SiO}_3 (aq) + \text{NaCl(aq)} \quad (2)$$

After the silica compound has settled, the water content that affects the moisture of the product can be removed by drying in the oven. The silica produced in this process is coarse silica [7]. The reactions that occur are as follows:

$$\text{H}_2\text{SiO}_3 (aq) \rightarrow \text{SiO}_2 (s) + \text{H}_2\text{O (aq)} \quad (3)$$

The data of the silica content produced in the separation process by using extraction can be seen in Table 1. In Table 1, it can be seen that the silica content of samples derived from fly ash was greater than the silica content derived from the bottom ash sample.

| Repeating | Silica content from bottom ash | Silica content from fly ash |
|-----------|-------------------------------|---------------------------|
| 1         | 4.22                         | 5.97                      |
| 2         | 4.18                         | 5.88                      |
| 3         | 4.28                         | 6.05                      |
| Mass of silica (gram) | 4.23±0.05                  | 5.97±0.08                 |
| Silica Content (%) | 21.31                     | 29.85                     |

The analysis results of silica compounds extracted by using FTIR can be seen in Figure 2 for sample derived from bottom ash and Figure 3 for samples derived from fly ash. The spectrum in Figure 2 yields several peaks which showing several functional groups. For clarity, it can be seen in Table 2 while spectrum in Figure 3 produces several peaks indicating some functional groups in samples derived from fly ash and for an explanation can be seen in Table 3.

![Figure 2. FTIR silica spectra from bottom ash sample](image-url)
Table 2. Interpretation of spectra on bottom ash sample

| Wave number (cm⁻¹) | Explanation                                      |
|-------------------|--------------------------------------------------|
| 460.99            | show Si-O bond [8]                               |
| 794.67            | bond deformation Si-O on SiO₄ [2]                |
| 1067.86           | the asymmetric stretching vibration of SiO       |
|                   | from silicoaksan Si-O-Si [9]                   |
| 1627.92           | stretch vibration of C=O from hemicellulose [2]  |
| 3452.58           | stretch vibration –OH (hydroxyl group) [2]      |

Figure 3. FTIR silica spectra from fly ash sample

Table 3. Interpretation of spectra on bottom ash sample

| Wave number (cm⁻¹) | Explanation                                      |
|-------------------|--------------------------------------------------|
| 466.77            | show Si-O bond [8]                               |
| 779.24            | bond deformation Si-O on SiO₄ [2]                |
| 779.60            |                                                 |
| 1051.20           | the asymmetric stretching vibration of SiO       |
| 1087.85           | from silicoaksan Si-O-Si [9]                   |
| 1639.49           | stretch vibration C = O of hemicellulose [2]    |
| 3450.65           | stretch vibration –OH (hydroxyl group) [2]      |

Based on the results of the spectra analyzes shown in table 3 and table 4, we can see that the peaks indicating the presence of some typical functional groups possessed by silica. However, there are some emerging peaks that cannot be identified. These peaks appear because of impurities from the analyzed samples that did not get separated at the time of sample extraction.

Analysis of the silica crystal structure derived from bottom ash and fly ash samples was also performed using X-ray diffraction (XRD). The obtained spectra are presented in figure 4 for a sample from bottom ash and figure 5 for a sample from fly ash. It can be seen from both images that the silica derived from the bottom ash has a spectral similarity to the silica derived from fly ash as well as in the FTIR analysis.
Figure 4. XRD spectra of silica from bottom ash sample

Figure 5. XRD spectra of silica from fly ash sample

The morphology of the studied silica surface is shown by the SEM, results in figure 6 is for samples from bottom ash for magnification of 10000x and figure 7 for magnification 40000x.
From figure 6 it is clear that the sample surface is uneven and consists of clusters, indicating the existence of fairly large grain sizes with uneven distribution on the surface of this as disclosed by Likes et al. (2012). Then clarified again with the magnification of 40000x in figure 7.

Figure 8 shows the morphology of the SEM silica surface for samples derived from fly ash for magnification of 10000x and figure 9 for 40000x magnification.

The result of SEM characterization for silica from fly ash shows quite different morphology with bottom ash sample. Although both samples showed uneven and clumped surfaces, the silica derived from the fly ash sample was more rounded. The same results are also obtained by Hayati and Astuti [10].

4. Conclusion
Based on the results of research that includes extraction and characterization, the following conclusions are obtained: (1) the silica content obtained from the bottom ash and fly ash of the Mpanau PLTU are
21.31% and 29.85%, respectively, (2) the FTIR and XRD spectrums of the bottom ash and fly ash samples shows the peaks which are characteristic of the silica compound, and (3) The silica morphology of the bottom ash and fly ash samples shows the sample surface is uneven and consists of clumps and the shape is grain.

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