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The Comparison Effects of NaOH and KOH as Solvents for Silica Extraction from Two Different Coal Fly Ashes

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Abstract

One of the environmental problems is the waste from the coal combustion process from coal power plants or other industries that use coal as an energy source. The combustion process produces coal fly ash, which will accumulate in the environment. Subsequently, much research about the utilization of coal fly ash has been developed. Silica extraction from coal fly ash is one of the methods that can be used to utilize coal fly ash. This study carried out silica extraction using the Direct Alkaline Leaching (DAL) method. The coal ash was contacted with alkaline solvents (KOH and NaOH) with the variations of concentrations and the leaching time. The leaching solution filtrate will be precipitated with the addition of HCl. The characteristics of this silica from CFA and CFA B were analyzed by using Scanning Electron Microscopy (SEM). Based on the results, it could be known that each of the coal fly ashes has different results for both alkaline solvents. CFA A has relatively less silica extraction results in both types of solvents. Meanwhile, CFA B gave higher silica extraction results with coal fly ash and solvent contact time for one hour.

Keywords: Coal, Fly ash, Leaching, Silica, Utilization

INTRODUCTION

The problem of waste and its handling and utilization is still the main topic in research with environmental themes to date. One of the research topics with environmental themes is waste from the combustion process that uses coal as its energy source. Based on data from Japan Coal Energy Center (JCOAL) in 2008, generally, coal ash contains 5-15% bottom ash and 85-95% fly ash (Rifa'I et al., 2010). Fly ash results from the combustion process in the form of very fine particles and most of the trace elements contained in it. Based on the previous research, it is known that fly ash or coal fly ash contains trace elements such as As, Se, F, B, and Hg. These trace elements are classified as heavy metals. Handling these elements by providing some additives is proven to withstand these metals that do not dissolve into the environment (Hanum et al., 2018; Hanum et al., 2019; Hartuti et al., 2017).

In Indonesia, research on handling heavy metal waste in Indonesia is very rare even though the amount of coal ash produced is very abundant. In general, research on coal ash in Indonesia leads to its use, such as in the chemical/industrial field as a metal adsorbent, in civil and construction uses as hollow blocks, and in agriculture as a mixed planting medium (Munir, 2008; Wardani, 2012; Wardhani et al., 2012). In previous research, the author has studied the characterization of coal ash from one of the industries in Indonesia for its use in agriculture (Hanum et al., 2020). From the characterization results, it is known that one of the main compositions of coal ash is silica.

Silica can be extracted from burning waste, one of which is rice husk ash. Mujiyanti et al. (2021) have extracted silica from rice husk ash using NaOH solvent and obtained silica as much as 8.59 grams with a content of 85.97%. Silica extracted from rice husk waste is widely used (Agung et al., 2013; Kalapathy et al., 2000). This silica can then be utilized, including silica gel (Tigabu, 2017), used for sewage treatment (Chuang et al., 2007; Masrofah, 2017), and as the main ingredient in the formation of TEOS, which is much needed in the industry (Mujiyanti et al., 2020). Silica extraction methods have varied from year to year over the last ten years. In general, silica extraction is carried out by researchers to be used as material for zeolite synthesis (Cornelius, 2019; Kamarudin et al., 2009; Matlob et al., 2012; Moreno et al., 2002). The most recent is its use as nano-silica, which can be used as a material for making catalysts and membranes (Aphane et al., 2019; Miricioiu et al., 2021). However, from the results of these researches, it is also known that the characteristics of coal fly ash and its use affect the appropriate silica extraction method (Hanum & Rahayu, 2021).

This study used two coal fly ash samples from coal combustion processes in different industries. Therefore, this study aims to determine the effect of different alkaline solvents used on the silica extraction results from these two types of coal fly ash. It is hoped that the information from this research can be a solution to handling coal fly ash waste in Indonesia.

METHODOLOGY

Materials and Instrumentals

Two samples of coal fly ash (CFA A and CFA B) are waste products from the coal combustion process in different industries, namely power plants and the cement industry in Java.

In this study, analysis of coal fly ash samples will be carried out using an X-ray fluorescence spectrometer (XRF; WDXRF S8 TIGER, Bruker AXS) to determine the percentage of SiO_2 contained in each sample. After the extraction process, the silica precipitate was analyzed using Scanning Electron Microscopy (SEM; HITACHI, TM4000Plus, Miniscope) to see the morphology of the silica obtained.

Procedure

Silica extraction was carried out using the Direct Alkaline Leaching method. This method is where the coal fly ash sample was reacted directly with alkaline solvents, namely NaOH and KOH, with varying concentrations of 1, 2, and 3 M, respectively, with certain contact times (1, 2, and 3 hours) at temperature 85-90 °C with a speed of 200 rpm. The Na_2SiO_3 solution was obtained after the specified contact time variation. The filtrate was separated from the residue and added 1 M HCl to form a silica precipitate.

RESULTS AND DISCUSSION

The process of stripping silica from coal fly ash is generally carried out using an alkaline solvent in NaOH. In addition to NaOH, KOH was also used to compare the silica yields obtained. The silica leaching process from coal fly ash begins with washing coal fly ash, where this process aims to dissolve the impurities contained in the coal ash sample so that the concentration of metal oxides that are not needed can be reduced and silica oxide levels can be maximized. Furthermore, the silica extraction process is carried out by adding NaOH/KOH base at a specific time variation. The formation of silica by NaOH and KOH is described in the following reaction, respectively:

Reaction with NaOH:

$$SiO_2 + 2NaOH \longrightarrow Na_2O.xSiO_2$$

Reaction with KOH:

$$SiO_2 + KOH \longrightarrow K_2SiO_3 + H_2O$$

Effect of solvent concentration NaOH and KOH

Samples of CFA A and CFA B from the combustion process of two different industries have their characteristics. Based on the X-ray Fluorescence Spectrometer (XRF), the percentage of silica oxide in two types of coal fly ash is 41.56% for CFA A and 45.35% for CFA B. After contact with heating between coal fly ash and NaOH and KOH was made, three concentration variations (1, 2, and 3 M) were obtained, as shown in Figures 1 and 2.

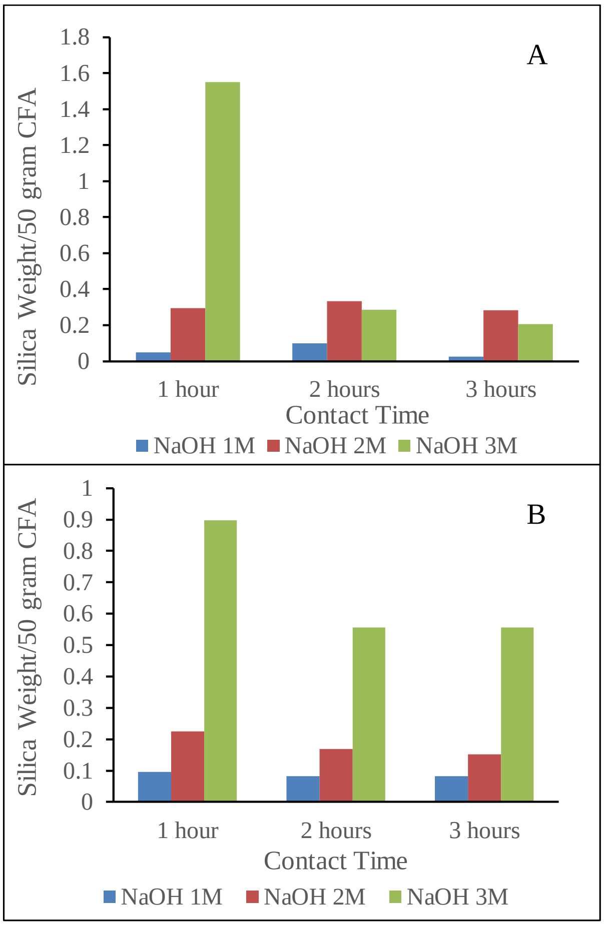


Figure 1. Comparison of silica extraction results from CFA A (A) and CFA B (B) samples with NaOH solvent

Figure 1 compares the amount of silica obtained for the extraction reaction using NaOH 1, 2, and 3 M solvents. Based on Figure 1, it can be seen that the CFA A sample gives relatively small silica yields compared to the amount of silica produced by the CFA B sample.

Concentration 2M NaOH gives better silica yield, among others. Meanwhile, the results of silica extraction for CFA B with NaOH solvent showed the more significant the concentration of NaOH, the greater the silica yield obtained.

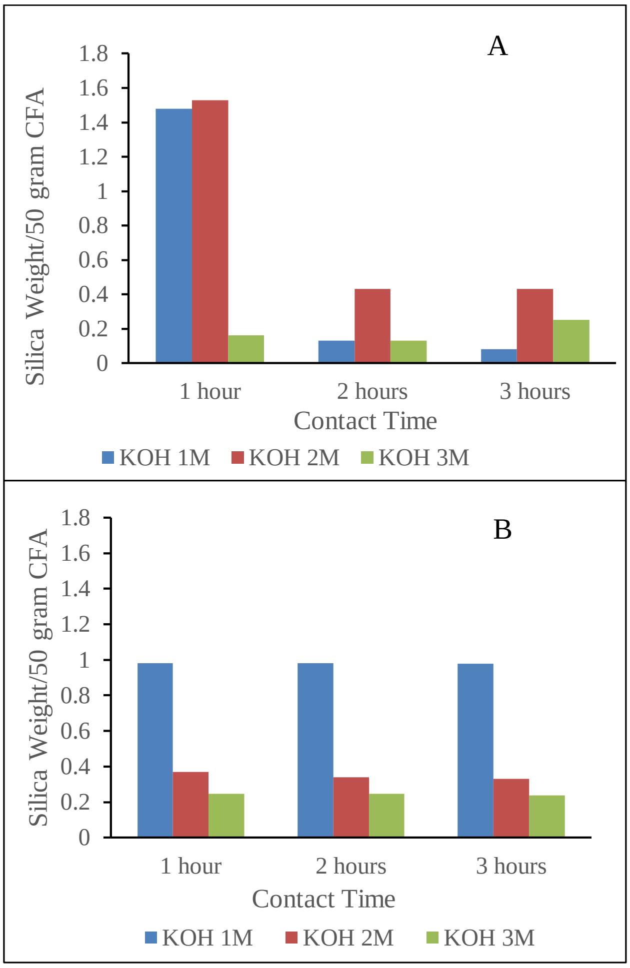


Figure 2. Comparison of silica extraction results from CFA A (A) and CFA B (B) samples with KOH solvent

CFA A and CFA B were also tested with alkaline KOH solvent under operating conditions. Figure 2 shows that with a different primary solvent, KOH, the amount of silica produced by CFA B to CFA A is relatively higher. In CFA B, the results were more consistent with the reversed pattern with the previous use of NaOH solvent. In CFA B, the higher the concentration of KOH used, the silica extraction results from coal fly ash became smaller, with the maximum yield shown by using 1 M KOH as a solvent. This is in line with what was stated in the existing reference that a high concentration of NaOH or KOH base will affect the activity of silica ions in solution so that the amount of silica formed is reduced (La Harimu et al., 2019).

Based on Figure 2, it can be stated that the silica in CFA B has a higher leaching tendency, with the average yields produced at each concentration of 1, 2, and 3 M NaOH being 0.174; 0.36; and 1.34 percent per 50 grams of ash sample, as well as 1.96; 0.69; and 0.48 percent per 50 grams of ash sample.

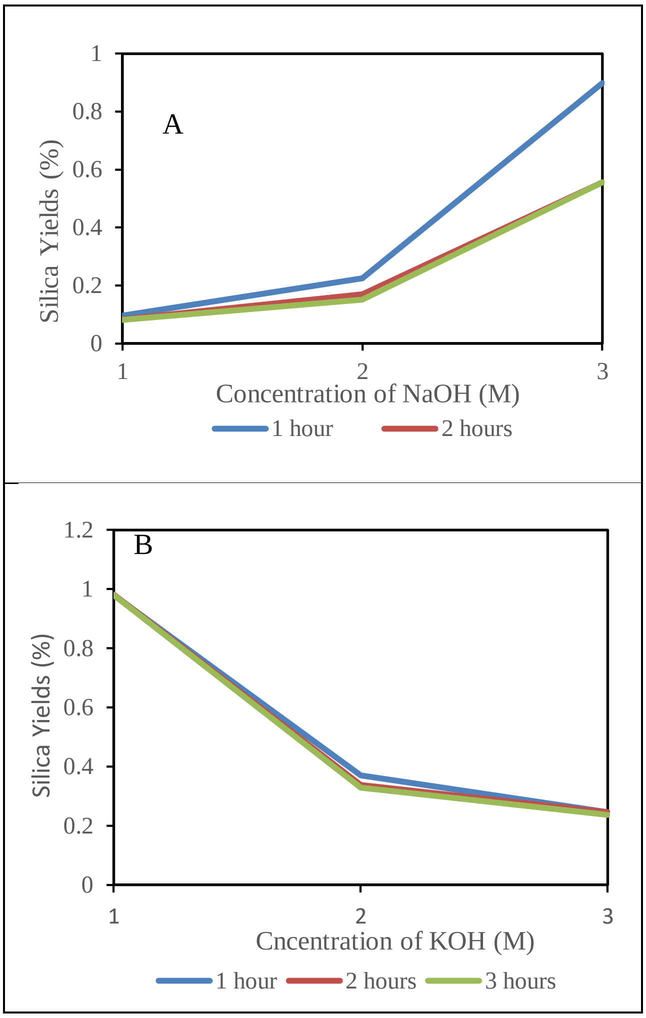


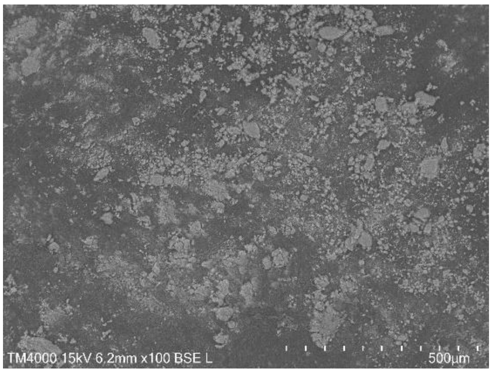
Figure 3. Effect of extraction time on the extraction yield of CFA B silica with NaOH (A) and KOH (B) solvents.

Effect of concentration of extraction time

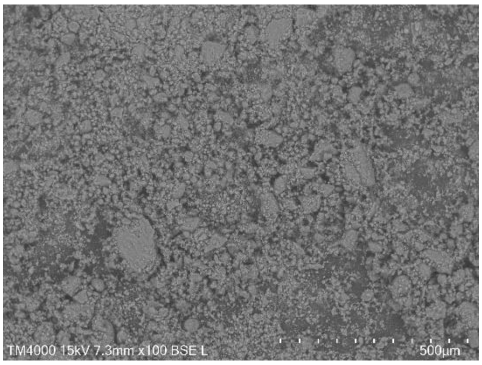
Samples of CFA A and CFA B were added with a solution of NaOH and KOH. The silica extraction process from coal fly ash was accompanied by heating at a temperature of 80 °C with a variation of extraction times of 1, 2, and 3 hours. Figure 3 shows the extraction time for CFA B with NaOH and KOH solvents. It can be concluded that the use of KOH solvent can increase the yields of silica separated from coal fly ash with a contact time between coal fly ash and KOH for 1 hour.

The SiO_2 characterization using SEM

The results of silica analysis of CFA B samples from the extraction process with NaOH and KOH using Scanning Electron Microscopy (SEM) are shown in Figure 4. SEM observations were carried out at a magnification of 10000 times to obtain the morphology of the silica extracted from these two alkaline solvents.



A



B

Figure 4. Photo of the appearance of silica extracted with NaOH (A) and KOH (B) with SEM for CFA B samples with Scanning Electron Microscopy (SEM)

Based on Figure 4, it can be seen that with NaOH the surface morphology is more rigid and dense. Likewise, the particles on the surface with NaOH solvent are more uneven than with KOH solvent. This shows that the characteristics of the silica produced from the leaching process with these two solvents have differences. Therefore, further research is needed to study the characteristics of the extracted silica from each of these solvents in more detail.

CONCLUSION

Between two different types of coal fly ash, it is known that the extraction yield of CFA B is more stable and greater than CFA A for both types of solvents. And CFA B has a higher yield with KOH, which is 1.96%, with a KOH concentration of 3 M at a contact time of 1 hour.

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