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Rice Husk Ash Characterization and Utilization as a source of Silica Material

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Rice husk ash is a waste from biomass power plants. Thus, the characterization and utilization of rice husk ash for silicon source was studied showed in this research. X-ray Diffractometer (XRD), X-ray Fluorescence Spectrometer (XRF), and Scanning Electron Microscope (SEM) techniques were used to examine the components of rice husk ash before and after extraction. Initially, components from rice husk ash were investigated using the XRF technique, which revealed a silicon (Si) value of 89.22%. Furthermore, trace metals detected in rice husk ash include K (7.27%), Ca (1.68%), Mn (0.33%), and Fe (0.25%). Geographical conditions and the year of rice harvest contributed to differences in composition. Hydrothermal and silica precipitation techniques were used to extract silicon from rice husk ash. Finally, XRD, XRF, and SEM techniques were used to examine silica/silicon dioxide (SiO_2). The component of silicon dioxide (SiO_2) recovered from rice husk ash extraction in NaOH 3M and HCl 2M conditions was 80.2%. The amorphous form of silicon dioxide (SiO_2) generated from rice husk ash is used in a range of industries, including petroleum, rubber, catalyst compounds, construction materials, desiccant, and food. As a result of this research, a waste utilization concept and increased value from rice husk ash was developed, resulting in a circular economy in biomass power plants as well as good health and well-being (Sustainable Development Goal: SDG3) for the community.

1. Introduction

In the AEDP 2015, Thailand set a target of increasing renewable energy by 30% by 2036, with biomass power plants being a significant target of 5,570 MW. As a result, in recent years, the number of very small power plants (VSPP), small power plants (SPP), and power plants has increased. Due to Thailand's agricultural land, rice husk is a well-known biomass material fuel for VSPP. Rice husk has a high efficiency for biomass powerplants, with a calorific value of 15,217.20 KJ Kg^{-1}, which is comparable to coal (Yadav J.P., Singh B.R., 2011). The rice husk biomass power plant's activities began with the transportation of rice husk to a storage tank, followed by its feeding into the combustion chamber, the transmission of heat energy to the boiler, and the operation of the steam turbine. The biomass combustion process produces rich husk ash. Although rice husk ash can be sold, it can pollute the air and pose environmental management issues. Then, biomass powerplant was release particulate matter (PM2.5 and PM10) released at a rate of 30-80 mg kw^{-1} that can be enter to the lungs. As a result, specific matter in biomass power plants must be managed (WHO., 2005). Rice husk ash is a waste product from biomass power plants, and fly ash is a fine powder that ranges in size from 1 µm to 200 µm. A great deal of research has focused on possible rice hush ash utilization that cheap cost as industrial waste (Battegazzore D., 2014). However, the rice husk ash utilization is not enough, find one solution was silica extraction from rice husk ash. Physical rice husk ash from biomass power plants has either white or black particular. The major chemical component of rice husk ash is silica. Pengthamkeerati et al., (2008) found a silica component 80% from fly ash. Silica or silicon dioxide (SiO_2) is an inorganic component

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that can be extracted from rice husk ash, the oxide and silicon that can be found. Silica is a basic material that has various technological applications, for thermal insulators and as a filler composite (Kamari, S., Ghorbani, F., 2020). There are three types of silica structure: quartz, tridymite, and cristobalite (Todkar BS., Deorukhkar OA., 2016). However, synthetic amorphous silica (SAS), which comprises silica gel, precipitation silica, and silica fume, is a highly flexible kind of silica. This substance can be used in a variety of sectors, such as a biodiesel catalyst, ion exchange, and heavy metal absorption (Ex: Hg, Pd, Cd, Zn). Furthermore, it can be utilized in silicone rubber, cosmetics, and the food sector (Todkar BS., Deorukhkar OA., 2016, Babaso PN., Sharanagouda H., 2017). Previous research showed that the amorphous silica contained in rice husk ash can be soluble with NaOH and pH condition more than 10 (Fernandes I.J., et al., 2017). Prominent silica extraction methods include as sol-gel technology and hydrothermal processes. Sol-gel technology is promoted within nano material extraction and is presented production such as fiber, aerogel, xerogel, powder and coating film for industrial materials (Patil R., et al., 2014). In term of hydrothermal process can be crystal synthetic in chemical reaction with optimum pressure and temperature. As a result, the goal of this study was to look into the production and purity of silica from rice husk ash.

2. Material and Methods

2.1 Rice husk ash

Rice husk ash (Figure 1) was obtained from Thanyakit Nakhonpathom (2521) Co., Ltd. This company is a biomass very small power plant (VSPP). Rice husk was burned at 800-900 ℃ for electricity generation and then boiler heated, finally turbine is operated. The major component of rice husk ash from biomass the power plant was silicon (Si) that allowed silica extraction. Elemental analysis from rice husk ash was studied with XRF (X-ray Fluorescence Spectrometer).

Figure 1 Fly ash from Thanyakit Nakhonpathom (2521) Co., Ltd.

Table 1 shows the components of rice husk ash from the biomass power plant (Analyzed from XRF). The major component of rice husk ash was silica. These data confirmed the major component from rice husk ash was silica (Si). Therefore, rice husk ash from the biomass power plant was suitable for silica extraction.

Table 1 Component of rice husk ash from Thanyakit Nakhonpathom (2521) Co., Ltd.

Component	Si	P	S	K	Ca	Mn	Fe	Zn
Percentage (%)	89.22	0.94	0.28	7.27	1.68	0.33	0.25	0.02

Silica (Si) was the predominant compound (89.22%) and other compounds were present in significant quantities, including K (7.27%), Ca (1.68%). The structure of rice husk ash silica in this study was amorphous and crystalline.

2.2 Extraction and characterization of silica from rice husk ash

Rice husk ash was prepared before extraction by oven drying at 70℃ for hour, then storing in a desiccator. Rice husk ash was extracted by two molar, three molar and four molar NaOH with fly ash: NaOH ratio 1 g :20 ml (Figure 2A), respectively. It was boiled at 90 ℃ for 24 hours, then filtered, dried, and weighed.

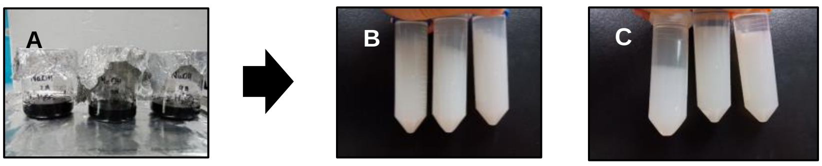

Figure 2 (A) Fly ash with different concentration of NaOH, (B) Sample was settled with H_2SO_4 and (B) Sample was settled with HCl

The fly ash was settled after extraction, with a settled condition 2 molar of HCl and H_2SO_4 (Figure 2B, C), respectively. The pH was adjusted to 4 then centrifuge at 5,000 rpm within 3 times. Finally, it was dried at 105 ℃ for 24 hours, then white precipitate was stored into desiccator (Patil R., et al., 2014, Buas de Lima S.P., et al., 2011). The quality of silica extraction was measured by X-ray Fluorescence Spectrometer (XRF), and X-ray Diffractometer (XRD). Morphology was measured with Scanning Electron Microscope (SEM). Scanning Electron Microscope (SEM) principal is primary electron release with 100-30,000 EV with atmosphere pressure 10^{-5} to 10^{-7}, then signal from electrons are released, it is displayed on the sample surface.

3. Results and Discussions

3.1 Chemical composition from silica extraction

SiO_2 influenced a number of elements, including geographical and incinerating circumstances, acid pre-treatment, and crop type. (Zou Y., Yang T., 2019). The rice husk ash from biomass power plant was characterized by XRF analysis. The trace elements most found in rice husk ash are K, Ca, Mn, Zn, and Fe (Table 1) with a difference of composition due to geographical factors, year of harvest and analytical methods (Zou Y., Yang T., 2019). The results show an 89.22% silica concentration (Table 1), which was transformed to SiO_2. Silica extraction with NaOH and precipitation with HCl and H_2SO_4 are shown in table 2. There were four samples with different conditions. The highest result of SiO_2 content was 80.2% that was obtained from extraction and settled conditions with NaOH 3M, and HCl 2M, respectively. As a result, the NaOH 3M and HCl 2M are suitable for SiO_2 extraction and settled conditions.

Table 2 Chemical components after extraction with different conditions

Chemical component	**Percent (%)**			
	Sample 1 (NaOH 2M, HCl 2M)	**Sample 2** (NaOH 3M, HCl 2M)	**Sample 3** (NaOH 2M, H_2SO_4 2M)	**Sample 4** (NaOH 3M, H_2SO_4 2M)
SiO_2	78.1	80.2	59.0	55.4
Cl	11.1	10.0	0.112	773 PPM
Na_2O	9.69	8.72	15.3	17.1
K_2O	0.556	0.351	0.728	0.575
Al_2O_3	0.333	0.466	0.322	0.262
P_2O_5	0.102	0.116	0.147	0.152
SO_3	639 PPM	552 PPM	21.3	23.1
Fe_2O_3	-	129 PPM	-	-
ZnO	95.8 PPM	-	-	-
ZrO_2	47.8 PPM	-	-	-

This SiO_2 research was compared to other researches (Table 3). The table presents the percentage of silica with different extraction methods. The largest amount of silica can be extracted with hydrothermal method.

Table 3 The comparison of material method, percentage of silica and structure in research

Material	**Method**	**Silica (%)**	**Structure**	**Reference**
Bottom ash	Alkaline fusion and hydrothermal conversion methods	78.0	Amorphous	Amin N., et al., 2015
Fly ash	Alkaline fusion	65.0	Amorphous	Yao Z., et al., 2010
Fly ash	Organic acid/inorganic alkali/ultrasonication-assisted joint process	51.0	Amorphous	Gao M., et al., 2017
Rice husk ash	Silica Extraction by Hydrothermal Method	80.2	Amorphous	This research

3.2 Structural and morphological composition

SiO_2 XRD pattern in 2-Theta with 20-25 degree can be formed from a 2M NaOH and HCl solution (Figure 3). NaCl was presented in the pattern that was follow in the reaction between NaOH and HCl, as illustrated in equation 1.

$$NaOH + HCl \longrightarrow NaCl + H_2O \quad (1)$$

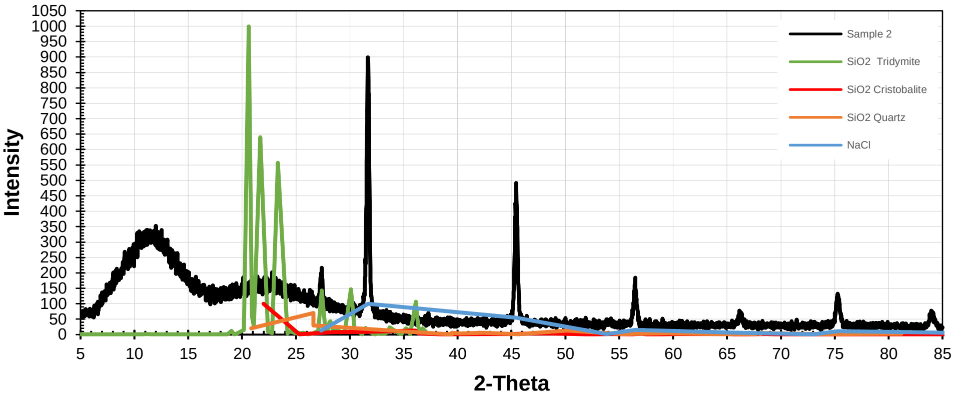

Figure 3 XRD Pattern with NaOH 2M, HCl 2M condition and NaOH 3M, HCl 2M

Rice husk ash was extracted with NaOH and HCl that can be increase the amorphous. Rice husk ash had already been found to contain amorphous silica, according to previous research (Patil R., et al., 2014). Impurities were removed from the fly ash using HCl solution that following the reaction with NaCl crystals appeared. In term of scanning electron microscope (SEM) was presented morphological characteristics of fly ash that was hydrothermal extraction method (Figure 4A, B). Extraction conditions with NaOH and HCl at various concentrations revealed an amorphous and rough surface. Silica amorphous, on the other hand, can be used in the petroleum, rubber, cement, and food industries.

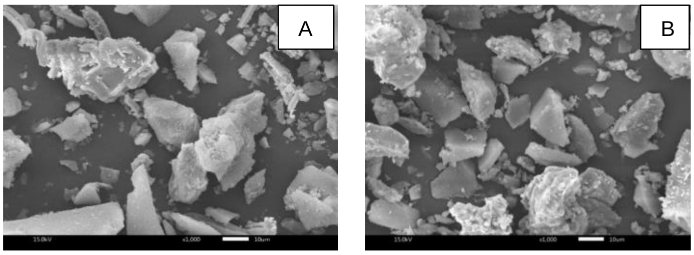

Figure 4 SEM Pattern (1,000X) with (A) NaOH 2M, HCl 2M condition and (B) NaOH 3M, HCl 2M

Equation 2 was present the reaction between NaOH and H_2SO_4 and convert to Na_2SO_4, respectively. Therefore, Na_2SO_4 was showed in XRD pattern.

$$NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + H_2O \quad (2)$$

Figure 5 (A) was present XRD pattern from NaOH 2M, and H_2SO_4 2M. The silica structure was amorphous at 2-Theta 20-23 degrees. Moreover, silica structure was also crystalline at 2-Theta 23.32 degrees, in term of Na_2SO_4 was present at 2-Theta 19, 38.62, and 48.78 degrees, respectively. Figure 5 (B) was present XRD pattern from NaOH 3M, and H_2SO_4 2M. The major silica structure was amorphous at 2-Theta 20-22 degrees. The crystalline silica structure was less at 2-Theta 23.32 degrees, while Na_2SO_4 was present at 2-Theta 19, 38.62, and 48.78 degrees.

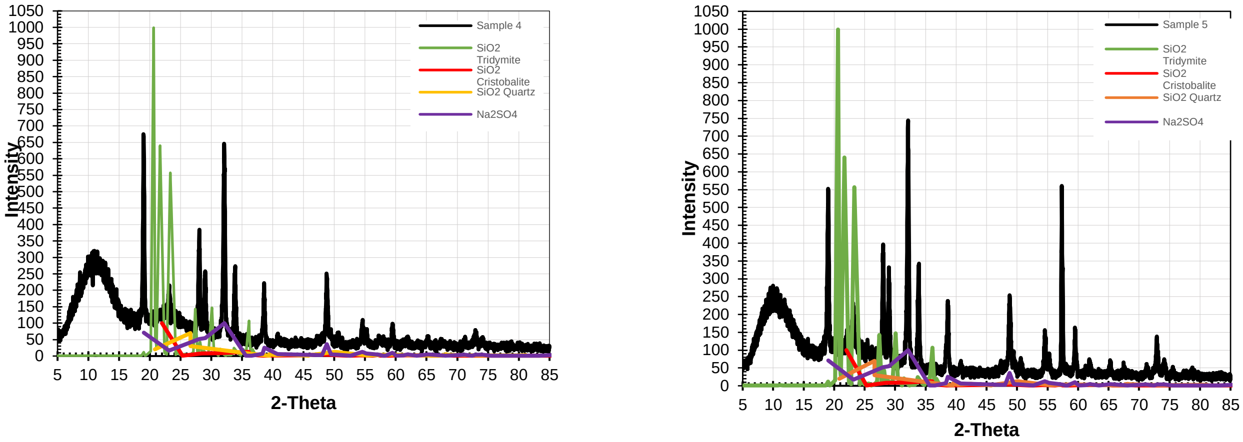

Figure 5 (A) present XRD pattern from NaOH 2M, and H_2SO_4 2M and (B) present XRD pattern from NaOH 3M, and H_2SO_4 2M

Rice husk ash structure analysis with the XRD technique was found in amorphous and crystalline in terms of tridymite, cristobalite and quartz. The different concentration of NaOH had a similar chemical composition, but the amount of precipitation was different. In term of NaOH 3M was found to have the highest of precipitation. From SEM pattern was present in figures 6 (A, B), it can be estimated that the size range of the aggregate in the silica obtained was 10 µm.

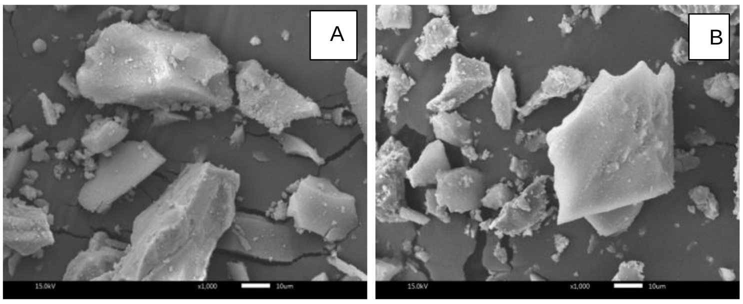

Figure 6 (A) present SEM pattern (1,000X) from NaOH 2M, and H_2SO_4 2M and (B) present XRD pattern from NaOH 3M, and H_2SO_4 2M

Impurities of Na, S, K, Cl, and Al were found in the silica product. The Na and S elements were obtained from NaOH and H_2SO_4, which was used in the extraction and precipitation process, however it was not completely wash. Thus, rice husk ash can be utilized and increased value for biomass very small power plants.

4. Conclusions

Amorphous silica was produced from rice husk ash by NaOH, HCl and H_2SO_4. Rice husk ash from biomass power plants can be extracted with NaOH, HCl and H_2SO_4. The SiO_2 content obtained from extraction and settling with NaOH 3M and HCl 2M was 80.2%. Combining NaOH with H_2SO_4 yielded amorphous silica (SiO_2) in the form of tridymite. As a result, NaOH 3M and HCl 2M were shown to be the suitable conditions for silica extraction. This research was showed that rice husk ash can be used to raw material for silica production. Finally, the waste utilization concept in this research can be air pollution decreasing that lead to good health and well-being (Sustainable Development Goal: SDG3) for community.

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