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## Synthesis of Ammonium Silicate Liquid Fertilizer from Rice Husk Ash

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### A B S T R A C T

This study aims to synthesize liquid ammonium silicate fertilizer ( $(\text{NH}_4)_2\text{SiO}_3$ ) from rice husk ash and to determine the effects of varying ammonium hydroxide ( $\text{NH}_4\text{OH}$ ) concentration and reaction temperature on the resulting silica (Si) and nitrogen (N) content. Rice husk ash is used as a silica source because it contains up to 82%  $\text{SiO}_2$ . The research process includes three main stages: raw material preparation; silica extraction using 10% NaOH at 80°C for 120 minutes; and a synthesis reaction between the extracted silica and an  $\text{NH}_4\text{OH}$  solution (5–25%) at 30–110°C for 60 minutes. Silica content analysis was carried out using UV-Vis spectrophotometry, while nitrogen content was analyzed using the Kjeldahl method. The results showed that increasing  $\text{NH}_4\text{OH}$  concentration and reaction temperature significantly increased silica content, while increasing temperature tended to decrease nitrogen content due to ammonia volatility. The best conditions were obtained at a  $\text{NH}_4\text{OH}$  concentration of 25%, a reaction temperature of 70°C, a silica content of 5.2701%, and a nitrogen content of 17.1637%. The results meet the SNI 02-6681-2002 standard for liquid macro compound fertilizers, which requires a minimum content of 4% for silica and nitrogen. Thus, rice husk ash has great potential as an alternative raw material for the manufacture of environmentally friendly ammonium silicate liquid fertilizers.

#### Contribution to Sustainable Development Goals (SDGs):

SDG 2: Zero Hunger

SDG 9: Industry, Innovation, and Infrastructure

SDG 12: Responsible Consumption and Production

SDG 13: Climate Action

## 1. INTRODUCTION

### 1.1. Research Background

Indonesia is an agrarian country highly vulnerable to the impacts of climate change, exceptionally prolonged droughts driven by rising global temperatures. These conditions have led to a significant reduction in water availability for agricultural purposes, thereby decreasing the productivity of staple crops such as rice and threatening national food security. As the third-largest rice producer in the world [1], Indonesia generates abundant rice husk as agricultural waste, which is often burned or discarded

without further use. This practice not only contributes to environmental pollution but also overlooks the potential of rice husk ash as a sustainable agricultural input. Optimizing the use of this waste aligns with efforts to promote circular-economy principles and develop environmentally friendly agricultural technologies.

Rice husk ash is known to contain a high concentration of silica ( $\text{SiO}_2$ ), ranging from 94% to 96% [2], making it a promising raw material for the synthesis of liquid ammonium silicate fertilizer. Ammonium silicate combines two essential plant nutrients—silica and nitrogen—that synergistically improve drought resistance and enhance vegetative growth. Silica deposits in plant epidermal tissues form a protective layer that reduces



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transpiration and water loss [3], while ammonium ions contribute to the plant growth, cell maintenance, and leaf expansion [4]. The synthesis of liquid ammonium silicate fertilizer typically involves three main stages: (1) preparation of rice husk ash as the silica source, (2) extraction of silica using an alkaline solution such as sodium hydroxide to form soluble sodium silicate, and (3) reaction of the extracted silica with ammonium hydroxide under controlled temperature conditions to produce liquid ammonium silicate. This approach not only transforms agricultural waste into a high-value fertilizer product but also supports sustainable farming practices that enhance crop resilience to climate-induced stress.

## 1.2 Literature Review

Rice husk ash is one of the most common types of agricultural waste. It is generally underutilized and is often burned or discarded without further use. Rice husk ash has greater value when used as the primary raw material for fertilizer production, particularly for liquid ammonium silicate fertilizer. The chemical composition of rice husk ash is shown in Table 1 [5].

**Table 1.** Composition of Compounds in Rice Husk Ash

No	Nutrient	Component (%)
1	Silica	92,8
2	Sodium Oxide	2,65
3	Phosphorus Pentoxide	1,07
4	Potassium Oxide	1,02
5	Iron (III) Oxide	0,31
6	Magnesium Oxide	0,2
7	Sulphur Trioxide	0,13
8	Titanium Dioxide	0,11
9	Other	1,25

From Table 1, the largest component of rice husk ash is silica, at 92.8%, which has the potential to be used as the main raw material for the production of ammonium silicate liquid fertilizer.

The high silica content in rice husk ash makes it a potential source for extraction using the alkaline extraction method, which is based on the solubility of silica in basic solutions such as sodium hydroxide (NaOH). Chemically, the solubility of silica (SiO<sub>2</sub>) increases with the concentration of hydroxide ions (OH<sup>-</sup>) in the solvent. At pH values below 10, silica remains in a stable solid oxide form with very low solubility. However, when the pH exceeds 10, hydroxide ions react with surface silanol (Si-OH) groups on silica particles to form soluble silicate ions (SiO<sub>3</sub><sup>2-</sup>), thereby significantly enhancing extraction efficiency [6]. Therefore, silica extraction from rice husk ash is typically carried out using an alkaline solvent, such as NaOH, to produce a sodium silicate solution, which is then neutralized with acid to precipitate pure silica.

The extracted silica is subsequently reacted with ammonium hydroxide (NH<sub>4</sub>OH) to synthesize liquid ammonium silicate fertilizer ((NH<sub>4</sub>)<sub>2</sub>SiO<sub>3</sub>). In this process, ammonium hydroxide serves not only as a reactant forming the silicate compound but also as a nitrogen source essential for plant growth. Variations in NH<sub>4</sub>OH concentration and reaction temperature are crucial for determining the final product's silica and nitrogen content. Higher concentrations of ammonium hydroxide provide more ammonium ions (NH<sub>4</sub><sup>+</sup>) in the reaction system, thereby increasing the nitrogen content in the resulting liquid fertilizer [7]. In

addition, higher reaction temperatures can accelerate dissolution and reaction rates between silica and ammonium hydroxide; however, excessively high temperatures may increase ammonia volatilisation, thereby reducing total nitrogen content. Therefore, optimizing solvent concentration and reaction temperature is essential to produce high-quality liquid ammonium silicate fertilizer that meets nutrient composition standards.

## 1.3. Research Objective

This research aims to synthesise liquid ammonium silicate fertiliser from rice husk ash and to determine the effects of ammonium hydroxide solvent concentration and reaction temperature on the silica and nitrogen content of the resulting fertiliser.

## 2. MATERIALS AND METHODS

### 2.1. Materials and Tools

The materials used in this research were rice husk ash from agricultural waste of the farmer group in Menganti, Gresik, which will be used for its silica content and sodium hydroxide (NaOH) 10%, hydrochloric acid (HCl) 37%, ammonium hydroxide (NH<sub>4</sub>OH) 25%, and distilled water, which were purchased from CV. Chemical Indonesia Multi Sentosa.

The equipment used in this research included a series of extraction tools consisting of a 500 ml beaker, a magnetic stirrer hot plate, a thermometer, and stands and clamps.

### 2.2. Research Procedure

#### 2.2.1 Raw Material Preparation Process

Rice husk ash was collected as agricultural waste from the Menagngti area of Gresik, East Java. It was then reduced in size using a knife mill and sieved to obtain a 100-mesh powder. XRF analysis of this powder determined its composition.

#### 2.2.2 Silica Extraction

Rice husk ash that has been sieved to a size of 100 mesh, then weighed as much as 20g and then added 160 mL of 10% NaOH solution. The extraction process takes place at 70 C, with stirring for 2 hours, to form sodium silicate. The extract is then put into a centrifuge tube to separate the solid (residue) from the sodium silicate solution (filtrate). The filtrate obtained is then added to 37% HCl dropwise while stirring until silica gel forms at pH 7. The silica precipitate will then be filtered and washed using to remove the remaining HCl in the silica gel. The silica gel is dried in an oven and ground in a mortar and pestle. The resulting silica is characterised by UV-Vis spectrophotometry.

#### 2.2.3 Silica and Ammonium Hydroxide Reaction

Dried silica weighed up to 10 g. Silica was reacted with 80 mL of ammonium hydroxide at concentrations of 5%, 10%, 15%, 20%, and 25%, and at reaction temperatures of 30 C, 50 C, 70 C, 90 C, and 110 C for 60 minutes. The reaction products were then transferred to a centrifuge tube to separate the solids (residue) from the ammonium silicate solution (filtrate). The resulting liquid ammonium silicate fertiliser was then analysed for nitrogen and silica content using the Kjeldahl method and UV-Vis spectrophotometry.

### 3. RESULT AND DISCUSSION

#### 3.1. Raw Material Analysis

Rice husk ash was used as the raw material in this study, which underwent a preparation stage that included size reduction using a knife mill and sieved to obtain a 100-mesh powder to increase surface area and improve extraction efficiency. XRF analyzed its content. The results of the initial analysis of the raw material content of rice husk ash are shown in Table 2.

**Table 1.** Composition of Compounds in raw material Rice Husk Ash

No	Nutrient	Component (%)
1	Aluminum Oxide	1
2	Silica	82
3	Phosphorus Pentoxide	2.6
4	Sulfur Trioxide	1.3
5	Potassium Oxide	5.95
6	Calcium Oxide	4.5
7	Titanium Oxide	0.13
8	Manganese (II) Oxide	0.592
9	Iron (III) Oxide	1.75
10	Cooper (II) Oxide	0.088
11	Zinc Oxide	0.043
12	Rubidium Oxude	0.024
13	Strontium Oxide	0.03
14	Rhenium (VII) Oxide	0.06

#### 3.2. Analysis of Silica Content from Rice Husk Ash Extraction

After obtaining the test results for the rice husk ash raw material, the silica extraction process was carried out. The extraction process was carried out to determine the silica content in rice husk ash using a 10% sodium hydroxide (NaOH) solvent, producing a sodium silicate solution ( $\text{Na}_2\text{SiO}_3$ ). The sodium silicate solution was then added with hydrochloric acid (HCl) to produce a silica precipitate. The formed silica precipitate would be filtered and washed with water to remove the remaining HCl. The silica precipitate was then dried in an oven. The silica product obtained from rice husk ash extraction needs to be analysed for silica content using UV-Vis spectrophotometry. The results of the silica content analysis from the extraction are shown in Table 3.

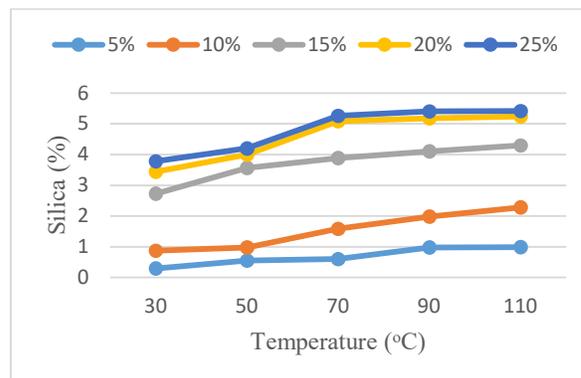
**Table 3.** Composition of Compounds in Rice Husk Ash

No	Nutrient	Component (%)
1	Silica	58,6

#### 3.3. Analysis of the Effect of Reaction Temperature on the Silica (Si) Content Produced Based on Variations in Ammonium Hydroxide ( $\text{NH}_4\text{OH}$ ) Concentration

After obtaining the silica content test results from the extraction, ammonium silicate fertilizer was prepared by mixing 10 g of silica into 80 mL of  $\text{NH}_4\text{OH}$  solution. The  $\text{NH}_4\text{OH}$  solution was used at five concentrations — 5%, 10%, 15%, 20%, and 25% — and each concentration was tested at five reaction temperatures: 30 °C, 50 °C, 70 °C, 90 °C, and 110 °C. The mixing process lasted for 60 minutes for each condition. Changes in Si content in the

liquid fertilizer resulting from reactions at each concentration-temperature combination are summarised in Figure 1, which shows how reaction temperature and base strength affect the solubility and stability of silicates in the liquid phase.



**Figure 1.** Graphic of the Relationship between Reaction Temperature and Silica Content at Various Ammonium Hydroxide Concentrations

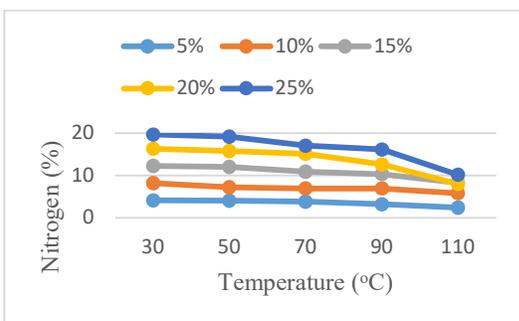
Figure 1 shows that the higher the reaction temperature and ammonium hydroxide concentration used, the higher the silica content in liquid ammonium silicate fertilizer. This increase occurs gradually, both as the temperature increases at a particular ammonium hydroxide concentration and as the ammonium hydroxide concentration increases at a constant temperature. The highest silica content was 5.4247% at a reaction temperature of 110 °C and a 25% ammonium hydroxide concentration.

#### 3.4. Analysis of the Effect of Reaction Temperature on the Nitrogen (N) Content Produced Based on Variations in Ammonium Hydroxide ( $\text{NH}_4\text{OH}$ ) Concentration

In addition to affecting silica content, reaction temperature and ammonium hydroxide ( $\text{NH}_4\text{OH}$ ) concentration also play important roles in determining the dissolved nitrogen (N) content in liquid ammonium silicate fertilizer. Variations in  $\text{NH}_4\text{OH}$  concentration (5%, 10%, 15%, 20%, and 25%) and reaction temperature (30°C, 50°C, 70°C, 90°C, and 110°C) affect the stability and solubility of nitrogen compounds in solution. Figure 2 shows the effect of these two parameters on the nitrogen content produced after the reaction has been running for 60 minutes.

Figure 2 shows that the higher the reaction temperature, the lower the nitrogen content in liquid ammonium silicate fertilizer. This decrease is due to increased evaporation and decomposition of ammonia ( $\text{NH}_3$ ) at higher temperatures, resulting in most of the nitrogen in the solution being lost to the air. Conversely, increasing the concentration of ammonium hydroxide ( $\text{NH}_4\text{OH}$ ) increases the nitrogen content of liquid fertilizer. This is because the higher the  $\text{NH}_4\text{OH}$  concentration, the more ammonium ions ( $\text{NH}_4^+$ ) are available to react with silica, thereby increasing the nitrogen content in the final product. Based on the research results, the highest nitrogen content was obtained at a reaction temperature of 30°C with an ammonium hydroxide concentration of 25%, namely 19.58%. This condition indicates that low temperature and high base concentration are the optimal combination for maintaining nitrogen content in liquid ammonium silicate fertiliser, as they minimise ammonia loss

while maximising the formation of stable nitrogen-silicate compounds.



**Figure 2.** Graphic of the Relationship between Reaction Temperature and Nitrogen Content at Various Ammonium Hydroxide Concentrations

#### 4. CONCLUSION

The analysis results showed that concentration and reaction temperature significantly influenced the final product's silica and nitrogen content. Increasing the ammonium hydroxide concentration increased nitrogen content and accelerated the ammonium silicate formation reaction, whereas increasing the reaction temperature increased silica solubility to a limited extent. However, excessively high temperatures reduced nitrogen content due to increased ammonia volatility. Optimum conditions were obtained at an  $\text{NH}_4\text{OH}$  concentration of 25% and a temperature of 70°C, yielding silica content of 5.27% and nitrogen content of 17.16%.

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