JIT Journal of Innovation and Technology
e-ISSN: 2721-8562; p-ISSN: 2721-8570
Vol. 7, No. 1, April 2026. Page: 19 – 28

Production of Sodium Silicate from *Imperata cylindrica* Ash by Sodium Carbonate-Assisted Alkaline Extraction

Ani Purwanti [1,*], Mukasi Wahyu Kurniawati [1] and Anak Agung Putu Susastriawan [2]

[1] *Department of Chemical Engineering, Faculty of Engineering, Universitas AKPRIND Indonesia, Jl. Kalisahak 28, Gondokusuman, Kota Yogyakarta, Daerah Istimewa Yogyakarta*
[2] *Department of Chemical Engineering, Faculty of Engineering, Universitas AKPRIND Indonesia, Jl. Kalisahak 28, Gondokusuman, Kota Yogyakarta, Daerah Istimewa Yogyakarta*

*Corresponding Author: ani4wanti@akprind.ac.id

Article history
Received: 17.01.2026
Revised: 22.02.2026
Accepted: 10.04.2026

DOI:10.31629/jit.v7i1.8463

Abstract
The ash of *Imperata cylindrica* (cogon grass) contains silica that can be utilized for sodium silicate production. This work investigated its extraction using a sodium carbonate-assisted alkaline process. To evaluate silica recovery, 25 g of cogon grass ash was extracted with sodium carbonate solution at 100 ± 5 °C under different extraction times, sodium carbonate concentrations, and solvent volumes. The resulting filtrate was concentrated to obtain sodium silicate solution, and the effectiveness of the extraction process was assessed through silica recovery. The results revealed that all operating variables investigated had a significant effect on silica recovery. The best result was obtained at 75 min extraction time, 25 wt% sodium carbonate concentration, and 350 mL solvent volume, with a silica recovery of 41.59%. The increase in silica recovery was attributed to enhanced silica dissolution and improved mass transfer between the solid and liquid phases. The increase in silica recovery was influenced by more effective silica dissolution during extraction. Even though the recovery was lower than that commonly obtained from rice husk ash, cogon grass ash can still be considered a promising alternative silica source.

Keywords: *Imperata cylindrica* ash; sodium silicate; water glass; silica extraction; alkaline leaching; biomass

1. Introduction

The growing demand for sustainable materials and environmentally friendly manufacturing processes has encouraged the utilization of biomass-derived waste as an alternative source of valuable industrial raw materials [1]. Agricultural residues and biomass ashes have attracted considerable attention because they contain significant amounts of silica that can be recovered and converted into value-added products such as sodium silicate, silica gel, zeolites, adsorbents, and geopolymer precursors [2]. The conversion of biomass waste into industrial chemicals not only reduces environmental burdens but also supports circular economy principles through waste valorization and resource recovery [1].

Sodium silicate (Na_2SiO_3), commonly known as water glass, is an important silica-based chemical widely used in detergents, adhesives, refractory binders, catalyst supports, coatings, foundry materials, and silica-based products [3].

DOI:10.31629/jit.v7i1.8463

Conventionally, sodium silicate is produced by high-temperature fusion of silica sand and sodium carbonate at temperatures above 1200 °C, resulting in high energy consumption and production costs [4]. Consequently, recent studies have focused on developing alternative silica sources from agricultural and biomass residues to improve the sustainability and economic feasibility of sodium silicate production [5].

Among various biomass resources, rice husk ash has been extensively investigated as a silica source due to its high silica content and widespread availability [6]. Recent studies have demonstrated the successful extraction of silica from rice husk ash, wheat straw ash, sugarcane bagasse ash, bamboo leaves, and other agricultural residues for the production of sodium silicate and silica-based materials [7], [8]. Biomass-derived silica offers several advantages over conventional silica sand, including lower processing temperatures, renewable availability, reduced environmental impact, and the utilization of waste materials that would otherwise be discarded [1], [8].

The production of sodium silicate from biomass ash generally involves alkaline extraction, in which silica reacts with alkaline agents such as sodium hydroxide or sodium carbonate to form soluble silicate species [9]. Previous studies have reported that extraction efficiency is strongly influenced by process variables including extraction time, alkali concentration, temperature, particle size, and liquid-to-solid ratio [10]. Increasing extraction time generally enhances silica dissolution by improving mass transfer between the solid particles and the extraction medium, whereas higher alkali concentrations promote silica breakdown through increased chemical reactivity. However, excessive operating conditions may reduce extraction efficiency due to solution saturation, increased viscosity, and precipitation phenomena [10].

One biomass resource that remains underutilized despite its abundance is *Imperata cylindrica* (cogon grass or alang-alang). This perennial weed is widely distributed throughout tropical and subtropical regions and is considered one of the most aggressive invasive plant species in agricultural and plantation areas [11], [12]. In Indonesia, large tracts of marginal and abandoned lands are dominated by *Imperata cylindrica* , creating ecological and economic challenges due to its rapid propagation and competition with cultivated crops [11]. Although management efforts have traditionally focused on eradication, the large biomass availability suggests significant potential for value-added utilization.

Recent investigations have revealed that ash derived from *Imperata cylindrica* contains appreciable quantities of silica suitable for advanced material applications [13]. Irzaman et al. [13] reported that silica obtained from cogon grass ash exhibited favorable purity and morphological characteristics, indicating its potential as an alternative silica precursor. Furthermore, the silica characteristics were found to depend strongly on combustion conditions, suggesting that properly processed cogon grass ash may serve as a viable feedstock for silicate-based products.

Despite extensive research on sodium silicate production from rice husk ash and other agricultural residues, studies involving *Imperata cylindrica* ash remain limited [14], [15]. In particular, information regarding the effects of extraction time, sodium carbonate concentration, and solvent volume on silica recovery from cogon grass ash is still scarce. Therefore, further investigation is required to evaluate the feasibility of utilizing *Imperata cylindrica* ash as a sustainable alternative silica source.

The objective of this study was to produce sodium silicate from *Imperata cylindrica* ash through sodium carbonate-assisted alkaline extraction. The effects of extraction time, sodium carbonate concentration, and solvent volume on silica recovery were investigated to determine the optimum operating conditions for sodium silicate production. The results are expected to provide scientific information regarding the utilization of cogon grass ash as a renewable silica resource and contribute to the development of sustainable biomass-based chemical products.

2. Materials and Methods

2.1 Materials

Imperata cylindrica (cogon grass) was collected from Yogyakarta, Indonesia. The biomass was cleaned with water to remove adhering impurities and subsequently dried in the sunlight. Sodium carbonate (Na_2CO_3), hydrochloric acid (HCl), and distilled water were used as reagents during the extraction process. All chemicals were of analytical grade and used without further purification.

Cogon grass was selected as the silica source due

DOI:10.31629/jit.v7i1.8463

to its abundance and reported silica content in previous studies [13], [14]. Sodium carbonate was employed as the alkaline extracting agent because it is widely used in the production of sodium silicate from silica-rich biomass ashes [3], [4].

2.2 Preparation of Cogon Grass Ash

The dried biomass was combusted to obtain cogon grass ash. The resulting ash was ground and sieved to obtain a relatively uniform particle size. The ash was subsequently dried and stored in airtight containers before extraction.

The preparation procedure was adopted from common biomass ash processing methods used for silica recovery from agricultural residues [5], [16], [17]. The combustion process converted the organic components into ash while concentrating the inorganic silica fraction.

2.3 Sodium Silicate Synthesis

Sodium silicate was produced through alkaline extraction of silica contained in cogon grass ash. The experimental setup consisted of a three-neck glass reactor equipped with a reflux condenser, thermometer, and mechanical stirrer.

A fixed amount of 25 g of ash was mixed with sodium carbonate solution and heated at 100 ± 5 °C under continuous stirring. Three process variables were investigated, namely extraction time, sodium carbonate concentration, and solvent volume. The operating conditions are summarized in Table 1.

Table 1. Experimental variables used in sodium silicate synthesis

Variable	Range
Extraction time	15–90 min
Sodium carbonate concentration	5–30 wt%
Solvent volume	150–350 mL
Temperature	100 ± 5 °C
Ash mass	25 g

The extraction process was based on the dissolution of silica into an alkaline medium, resulting in the formation of soluble sodium silicate species [3], [9], [10]. The formation of sodium silicate during alkaline extraction can be represented by Eq. 1.

$$SiO_2 + Na_2CO_3 \rightarrow Na_2SiO_3 + CO_2 \quad (1)$$

The selected operating ranges were based on preliminary experiments and previous studies involving sodium silicate production from biomass-derived silica sources [4], [10], [16].

2.4 Filtration and Concentration

After completion of the extraction process, the slurry was cooled to room temperature and filtered to separate the insoluble residue from the sodium silicate solution. The filtrate was then concentrated by removing excess water to produce water glass (sodium silicate solution). Filtration and concentration are essential stages in biomass-derived sodium silicate production because they determine the purity and concentration of the final product [3], [22].

2.5 Product Analysis

The resulting sodium silicate solution was analyzed to determine the contents of silica (SiO_2), sodium oxide (Na_2O), and water. Silica recovery was used as the primary performance indicator for evaluating the extraction process.

The percentage of silica recovery was calculated as (Eq. 2):

$$Silica\ Recovery\ (\%) = \frac{m_{SiO_2,extracted}}{m_{SiO_2,initial}} x100 \quad (2)$$

where:

$m_{SiO_2,\,extracted}$= mass of silica extracted in the sodium silicate solution (g)

$m_{SiO_2,\,initial}$= initial mass of silica contained in cogon grass ash (g)

The analytical approach is consistent with methods commonly employed in studies concerning sodium silicate synthesis from rice husk ash and other silica-rich biomass materials [3], [21], [22].

2.6 Data Analysis

The experimental data were evaluated to determine the influence of extraction time, sodium carbonate concentration, and solvent volume on silica recovery. The optimum operating conditions were determined based on the highest percentage of extracted silica obtained during the experiments.

The observed trends were interpreted using silica dissolution mechanisms and mass-transfer considerations reported in previous alkaline extraction studies [9], [10]. Comparative discussion with recent biomass-derived sodium silicate research

DOI:10.31629/jit.v7i1.8463

was also conducted to evaluate the feasibility of utilizing *Imperata cylindrica* ash as an alternative silica source.

3. Results and Discussion

3.1 Effect of Extraction Time on Silica Recovery

The influence of extraction time on silica recovery was evaluated while maintaining constant operating conditions, namely 25 g of cogon grass ash, 20 wt% sodium carbonate concentration, 300 mL solvent volume, and an operating temperature of 100 ± 5 °C under atmospheric pressure. The corresponding experimental results are presented in Table 2.

Table 2. Effect of extraction time on silica recovery.

Extraction Time (min)	SiO_2 Content (%)	SiO_2 Recovered (%)	Na_2O Content (%)	Water Content (%)
15	2.38	19.45	15.97	0.77
30	2.62	21.23	16.59	0.77
45	2.84	23.41	17.1	0.77
60	2.98	24.57	17.53	0.84
75	2.92	23.89	17.31	0.78
90	2.93	23.97	17.45	0.78

Based on the experimental data presented in Table 1, the relationship between extraction time and silica recovery can be represented empirically by the quadratic equation:

$$Y = -0.0016X^2 + 0.2266X + 16.256 \quad (3)$$

Where:

Y is the silica recovery (%)

X is the extraction time (min).

The empirical relationship described by Eq. 3 is valid only within the investigated operating range. The trend indicated by Eq. 3 is demonstrated in Fig. 1. Silica recovery increased from 19.45% (after 15 minutes of extraction) to the maximum value of 24.57% at one hour, which can be attributed to the continuous dissolution of silica in alkaline solution throughout the experiment. Extending the extraction time up to 90 minutes did not significantly affect silica recovery: that was in a narrow range of 23.89% and 23.97% at extraction times from 75 to 90 minutes, which indicates that the process was approaching equilibrium.

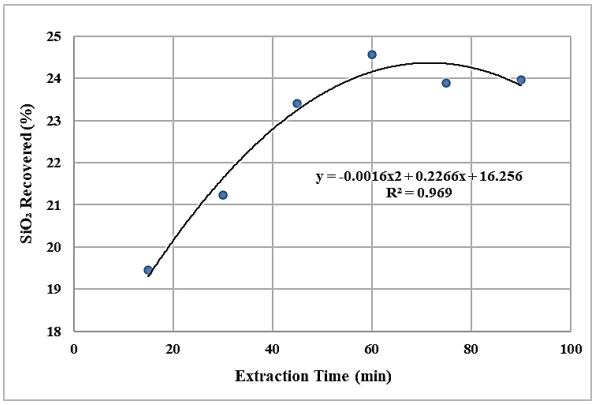

Figure 1. Effect of extraction time on silica recovery from *Imperata cylindrica* ash.

The first increase of silica recovery was mainly due to the combined effect of more efficient silica dissolution and higher mass transfer with solid ash particles contacting sodium carbonate solution. In the initial phase of extraction, the reduction in silica content creates a large concentration gradient between the solid and liquid phases which provides powerful driving force for dissolution of silica. As extraction continues, the concentration gradient diminishes and thus the system approaches equilibrium, leading to a decreased rate of extraction. This is indeed the second moment of such behavior and is made explicit by the negative coefficient of that refers to a quadratic term in Eq. 3, that long extraction times offer only small gains in silica recovery.

The observed trend suggests that silica dissolution occurred rapidly during the initial extraction period when a large concentration gradient existed between the solid ash particles and the sodium carbonate solution. During this stage, soluble silicate species were formed as silica present in the ash interacted with the alkaline medium. As extraction proceeded, the concentration gradient gradually decreased, reducing the dissolution rate and causing the extraction process to approach equilibrium conditions.

From the mass-transfer perspective, longer extraction time promotes diffusion of reactive species between solid and liquid phases. Consequently, more of the silica dissolves to the extraction media. Similar trends have been reported for silica extraction from rice husk ash and wheat straw ash [5], where extraction efficiency increased

DOI:10.31629/jit.v7i1.8463

with reaction time until equilibrium was reached [9], [10]. The small increase beyond 60 min promotes the idea that most of oxidizable silica released is dissolved already. As a result, the longer we extend the extraction time, the fewer benefits there will be with a greater increase in processing costs and energy consumption. For this reason, an extraction time of 75 min was selected as the optimum operating condition.

Compared with biomass sources such as rice husk ash, which often contain highly reactive amorphous silica, the extraction efficiency observed in cogon grass ash was lower. This difference may be attributed to variations in silica content, silica crystallinity, and the presence of other mineral components that can influence dissolution behavior [5], [13].

These findings suggest that extraction time is an important parameter during the initial stages of silica dissolution; however, excessive extraction periods do not necessarily result in proportional increases in silica recovery.

3.2 Effect of Sodium Carbonate Concentration on Silica Recovery

The influence of sodium carbonate concentration on silica recovery was investigated while maintaining constant operating conditions, namely 25 g of cogon grass ash, 350 mL solvent volume, an extraction time of 75 min, and an operating temperature of 100 ± 5 °C under atmospheric pressure. The corresponding experimental results are summarized in Table 3.

Table 3. Effect of sodium carbonate concentration on silica recovery.

Sodium Carbonate Concentration (wt%)	SiO_2 Content (%)	SiO_2 Recovered (%)	Na_2O Content (%)	Water Content (%)
5	2.06	15.39	16.65	0.46
10	2.89	21.61	17.65	0.71
15	3.09	23.31	18.31	0.84
20	4.29	32.09	19.02	0.91
25	4.97	37.74	19.26	1.32
30	4.63	35.93	18.79	0.94

Based on the experimental data presented in Table 2, the relationship between sodium carbonate concentration and silica recovery can be represented empirically by the following cubic equation (Eq.4):

$$Y = -0.0174X^2 + 1.5223X + 7.633 \quad (4)$$

Where:

Y is the silica recovery (%)
X is sodium carbonate concentration (wt%).

The empirical relationship is valid for sodium carbonate concentrations from 5 to 30 wt%, with an average relative error (R^2=0.9406). The trend predicted by Eq. 4 is illustrated in Fig. 2.

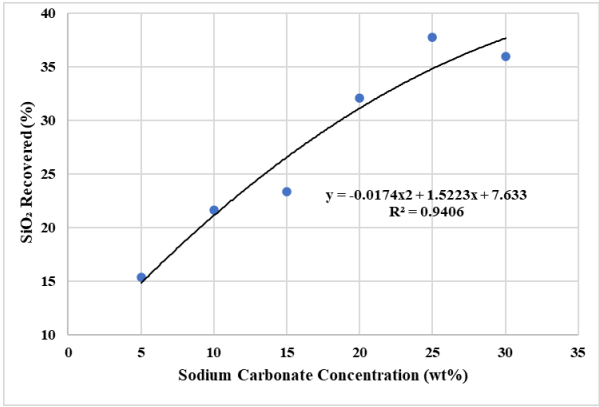

Figure 2. Effect of sodium carbonate concentration on silica recovery.

Increasing the sodium carbonate concentration from 5 wt% to 25 wt% significantly enhanced silica recovery from 15.39% to 37.74%. Simultaneously, the SiO_2 content of the resulting sodium silicate solution increased from 2.06% to 4.97%, while the Na_2O content increased from 16.65% to 19.26%. However, a further increase in sodium carbonate concentration to 30 wt% resulted in a decrease in silica recovery to 35.93% and a reduction in SiO_2 content to 4.63%.

The increase in silica recovery with sodium carbonate concentration can be attributed to the greater availability of alkaline species that promote the dissolution of silica from the cogon grass ash matrix. During the extraction process, sodium carbonate reacts with silica to form soluble sodium silicate species, allowing a larger fraction of silica to be transferred from the solid phase into the liquid phase. Higher sodium carbonate concentrations enhance the dissolution of silica and promote the formation of soluble sodium silicate. Consequently, increasing the alkali concentration enhances the chemical driving force for silica dissolution and improves the overall extraction efficiency.

The observed increase in Na_2O content with increasing sodium carbonate concentration further supports this mechanism. A higher concentration of sodium ions in the extraction medium facilitates the formation of sodium silicate, resulting in increased silica recovery. Similar results were reported, that higher alkalinity improved silica extraction from rice husk ash [9]. The same trends have also been

DOI:10.31629/jit.v7i1.8463

reported for sodium silicate production from rice husk ash and other silica-rich agricultural residues [3], [4], [16].

The decrease in silica recovery observed beyond the optimum concentration of 25 wt% indicates that excessive sodium carbonate does not necessarily improve extraction. At high alkali concentrations, the solution becomes increasingly concentrated, which may increase viscosity and reduce effective mass transfer between the ash particles and the surrounding liquid. In addition, the extraction medium may approach saturation with dissolved silicate species, thereby reducing the concentration gradient that drives silica dissolution. Similar limitations have been reported in alkaline extraction systems involving biomass-derived silica materials [5], [21].

The water content of the final sodium silicate solution also exhibited an increasing trend up to the optimum concentration, reaching 1.32% at 25 wt% sodium carbonate, before decreasing at 30 wt%. This behavior suggests that the extraction process was accompanied by greater dissolution of soluble species at intermediate alkali concentrations, whereas excessive alkali loading may have altered the equilibrium of the extraction system.

The empirical relationship described by Eq. (4) also reflects the observed extraction behavior. The positive linear coefficient indicates that silica recovery initially increases with sodium carbonate concentration, while the negative quadratic coefficient suggests the existence of an optimum concentration beyond which additional alkali provides diminishing returns. Therefore, the mathematical model adequately represents the experimental trend within the investigated operating range.

As for industrial application, determining the ideal sodium carbonate concentration is critical since excessive reagent usage is not only decreasing recovery rates of silica but also increasing chemical cost. At this sodium carbonate concentration 25 wt% appears to provide the most acceptable trade-off between extraction efficiency and reagent use, maximizing silica recovery (37.74%) and SiO_2 contents (4.97%), under the investigated conditions. In addition, the silica-extracted *Imperata cylindrica* ash have opened up another biomass resource for sodium silicate production as a potential alternative to sustainable methods; thus, it favours the prospect of biomass waste valorisation.

3.3 Effect of Solvent Volume on Silica Recovery

The effect of solvent volume on silica recovery was investigated while maintaining constant operating conditions, namely 25 g of cogon grass ash, 25 wt% sodium carbonate concentration, an extraction time of 75 min, and an operating temperature of 100 ± 5 °C under atmospheric pressure. The corresponding experimental results are summarized in Table 4.

Table 4. Effect of solvent volume on silica recovery.

Solvent Volume (mL)	SiO_2 Content (%)	SiO_2 Recovered (%)	Na_2O Content (%)	Water Content (%)
250	3.87	30.18	19.57	1.07
275	4.25	33.05	20.16	1.24
300	4.66	36.19	20.95	1.44
325	4.99	39.01	21.65	1.71
350	5.37	41.59	22.43	1.97
375	5.35	40.96	21.89	1.88

Based on the data in Table 4, the effect of solvent volume on silica recovery can be expressed by the quadratic equation shown in Eq. 5:

$$Y = -0.0006X^2 + 0.4466X - 46.627 \quad (5)$$

Where:

Y is the silica recovery (%)

X is the solvent volume (mL).

The equation is valid for solvent volumes between 250 and 375 mL, with an R^2 value of 0.9817. The trend predicted by Eq. 5 is illustrated in Fig. 3.

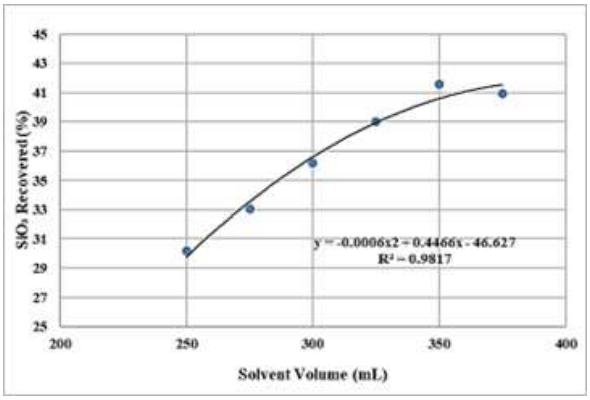

Figure 3. Effect of solvent volume on silica recovery.

Increasing the solvent volume from 250 mL to 350 mL continuously increased silica recovery from 30.18% to 41.59%. The SiO_2 content of the sodium silicate solution also increased from 3.87% to 5.37%, and the Na_2O content increased from 19.57% to 22.43%. However, silica recovery and SiO_2 content decreased to 40.96% and 5.35%, respectively, when the solvent volume was increased to 375 mL.

The increase in silica recovery with increasing

DOI:10.31629/jit.v7i1.8463

solvent volume can be attributed to the higher liquid-to-solid ratio available during the extraction. Larger solvent volumes provide a greater capacity for dissolving silicate species and reduce local saturation around the ash particles. At this condition, the concentration gradient between the solid and liquid phases is maintained, allowing silica dissolution to continue during the extraction process. Consequently, the overall extraction efficiency is improved.

In addition, a larger solvent volume improves the distribution of dissolved species throughout the extraction medium, facilitating mass transfer and reducing diffusion limitations around the ash particles. This phenomenon enables more effective interaction between the sodium carbonate solution and the silica-containing matrix, thereby increasing the formation of soluble sodium silicate. Similar observations have been reported for silica extraction from rice husk ash and other agricultural biomass residues, where increasing the liquid-to-solid ratio significantly enhanced silica dissolution and extraction performance [16], [21], [22].

The simultaneous increase in Na_2O content with increasing solvent volume also indicates that greater amounts of sodium silicate were formed during the extraction process. Meanwhile, the increase in water content up to the optimum solvent volume suggests that larger quantities of dissolved species were retained within the resulting sodium silicate solution.

As the amount of solvent added increases above 350 mL, silica recovery continues to decrease but at a lower rate than in previous steps, which indicates that extracting beyond an optimal volume does not significantly increase extraction performance. While larger solvent volumes mitigate the local saturation effects, cloying the solution with solvent dilutes reactive species in as well which lowers the effective concentration in the medium reducing its driving force of silica dissolution. Moreover, more solvent corresponds to additional liquid volume that needs concentration at a later point in the process during water glass production, and thus increases costs.

The trend observed experimentally is consistent with the empirical relationship described by Eq. (5). The positive value of the linear term indicates that increasing the solvent volume enhances silica recovery during the initial stage of the extraction process. However, the negative quadratic term implies that this improvement gradually diminishes, leading to an optimum operating point beyond which additional solvent contributes only a slight increase in extraction efficiency. Therefore, Eq. (5) provides a satisfactory representation of the silica recovery behavior within the range of solvent volumes investigated in this study.

From a practical and industrial point of view, the amount of solvent used during extraction is an important operating variable because it affects not only the efficiency of silica dissolution but also the subsequent concentration stage and the overall cost of the process. Within the range of conditions examined in this study, the use of 350 mL of solvent resulted in the highest silica recovery, reaching 41.59%, with a corresponding SiO_2 content of 5.37%. This result suggests that the selected solvent volume provides an appropriate compromise between effective silica extraction and economical solvent usage. Moreover, the successful recovery of silica from *Imperata cylindrica* ash indicates that this readily available biomass has considerable potential to be utilized as an alternative silica source for sodium silicate production through an alkaline extraction process.

3.4 Optimum Operating Conditions and Process Performance

The optimum operating conditions with the maximum silica recovery at 41.59% identified in this study were an extraction time of 75 min, sodium carbonate concentration of 25 wt%, and solvent volume of 350 mL. Silica extraction from cogon grass ash is governed by both chemical and physical phenomena. Extraction time controls the duration of silica dissolution, sodium carbonate concentration determines the chemical driving force for silica conversion, and solvent volume influences mass-transfer characteristics and saturation effects.

The interaction among these variables determines the overall efficiency of sodium silicate production. Optimization of these parameters is therefore essential for maximizing silica recovery while minimizing operating costs.

3.5 Comparison with Previous Studies

The utilization of biomass-derived ashes as alternative silica sources has received increasing attention in recent years due to their potential for waste valorization and sustainable material production. Various agricultural residues have been successfully converted into silicate-based materials, demonstrating the feasibility of transforming low-value biomass waste into value-

DOI:10.31629/jit.v7i1.8463

added products [23]. Table 5 compares the silica recovery obtained in this work with values reported for other biomass-derived silica sources.

Table 5. Comparison of silica recovery from different biomass sources.

Biomass Source	Extracting Agent	Silica Recovery (%)	Reference
Rice husk ash	NaOH	70–90	[3], [16]
Wheat straw ash	NaOH	60–80	[5]
Agricultural biomass ash	Alkali solution	50–80	[21]
Date palm ash	NaOH	55–75	[15]
Imperata cylindrica ash	Na_2CO_3	41.59	This study

The silica recovery obtained in the present study was lower than commonly reported for rice husk ash and wheat straw ash. This difference may be attributed to several factors. First, rice husk ash generally contains a higher proportion of amorphous silica, which is more readily dissolved in alkaline media. Second, many previous studies employed sodium hydroxide as the extraction agent, whereas sodium carbonate was used in the present work. Because sodium hydroxide exhibits stronger alkalinity, it generally promotes more efficient silica dissolution [9], [16].

Nevertheless, the successful production of sodium silicate from cogon grass ash demonstrates the feasibility of utilizing this abundant biomass resource as an alternative silica source. Given the widespread availability of *Imperata cylindrica* in tropical regions, its utilization could contribute to both biomass waste management and the development of sustainable silica-based materials.

3.6 Implications for Sustainable Sodium Silicate Production

The present study suggests that ash derived from *Imperata cylindrica* can be considered a potential alternative raw material for sodium silicate production because of its silica content. Although the percentage of silica recovered in this work was not as high as that reported for rice husk ash, the use of cogon grass still offers several practical advantages. This plant grows abundantly in many tropical regions, requires no cultivation, and is often removed because it interferes with agricultural activities. For that reason, utilizing its ash for industrial purposes may increase the economic value of a biomass resource that is generally treated as waste.

The conversion of cogon grass ash into sodium silicate also has relevance from an environmental perspective. Rather than being discarded after combustion, the ash can be processed further into a useful chemical product, supporting the concept of biomass waste utilization and resource recovery. In addition, the use of this renewable silica source may help reduce the dependence on conventional silica-bearing minerals, particularly natural silica sand, which is still widely used in sodium silicate production. Therefore, the approach investigated in this study offers not only a possible alternative source of silica, but also a simple strategy for improving the utilization of locally available biomass residues.

Future studies should focus on improving silica recovery through pretreatment methods, optimization of combustion conditions, and the use of stronger alkaline extraction systems. The application of stronger alkaline reagents such as NaOH has been reported to significantly improve silica extraction efficiency from biomass-derived ashes and may provide an alternative strategy for enhancing sodium silicate production from *Imperata cylindrica* ash [24]. Additional characterization using XRF, XRD, FTIR, and SEM analyses would also provide a more comprehensive understanding of silica extraction behavior and sodium silicate formation from *Imperata cylindrica* ash.

4. Conclusion

This study shows that *Imperata cylindrica* ash can be used as a raw material for producing sodium silicate through an alkaline extraction process with sodium carbonate. The extraction was strongly affected by extraction time, sodium carbonate concentration, and solvent volume, with optimum conditions achieved at 75 min, 25 wt% Na_2CO_3, and 350 mL solvent volume. Under these conditions, the maximum silica recovery reached 41.59%. The recovery value obtained in this work did not reach the level that is often reported for rice husk ash. However, the results show that cogon grass ash can still be considered a viable silica-bearing material, especially because it is widely available and has not been extensively utilized for industrial purposes. Further research should investigate process intensification strategies and advanced characterization techniques to improve extraction

efficiency and broaden the potential industrial applications of the resulting sodium silicate.

Acknowledgement

The authors would like to express their sincere gratitude to the Department of Chemical Engineering, Universitas AKPRIND Indonesia, Yogyakarta, Indonesia, for providing laboratory facilities and technical support during the completion of this research.

References

[1] M. Umer, M. A. Imteyaz, and M. A. Haque, "Innovative Valorization of Biomass Waste-Derived Sodium Silicate for Sustainable Construction Materials: A Review," Journal of Cleaner Production, vol. 475, 2024, doi: 10.1016/j.jclepro.2024.143608.

[2] D. Montini, F. Di Maria, and M. Polettini, "Recent Advances on Porous Siliceous Materials Derived from Waste Resources," Materials, vol. 16, no. 16, 2023, doi: 10.3390/ma16165542.

[3] M. F. Alnahhal, A. Castel, and S. Foster, "Hydrothermal Synthesis of Sodium Silicate from Rice Husk Ash," Cement and Concrete Research, vol. 180, 2024, doi: 10.1016/j.cemconres.2024.107542.

[4] A. Chithambar Ganesh, N. M. Noor, and M. A. Mannan, "Rice Husk Ash Based Sodium Silicate as the Alkali Activator," E3S Web of Conferences, vol. 559, 2024, Art. no. 04003, doi: 10.1051/e3sconf/202455904003.

[5] S. P. Ramasamy, M. A. Rahman, and K. Subramaniam, "New Insights into Method Development and Characterization of Amorphous Silica from Wheat Straw," Silicon, vol. 15, 2023, doi: 10.1007/s12633-023-02396-5.

[6] M. A. Pahlevi, M. H. Santoso, and A. R. Nugroho, "Production of Sodium Silicate from Rice Husk Ash with Regulatory Sets Magnesium," Tibuana: Journal of Applied Industrial Engineering, vol. 3, no. 1, pp. 47–52, 2020, doi: 10.36456/tibuana.3.01.2200.47-52.

[7] I. Hamidu, A. M. Abdullahi, and M. S. Gana, "Synthesis of Silica and Silicon from Rice Husk Feedstock: A Review," Results in Engineering, vol. 25, 2025, doi: 10.1016/j.rineng.2025.104392.

[8] Y. Du, M. K. Hossain, M. R. Karim, and M. A. Islam, "A Review of Biomass Wood Ash in Alkali-Activated Materials," Recycling, vol. 8, no. 5, 2024, doi: 10.3390/recycling8050161.

[9] M. F. Alnahhal, A. Castel, and S. Foster, "Mechanism of Silica Dissolution and Sodium Silicate Formation from Rice Husk Ash under Hydrothermal Conditions," Cement and Concrete Composites, vol. 146, 2024, doi: 10.1016/j.cemconcomp.2024.105281.

[10] O. Owoeye, S. O. Afolabi, and A. O. Ajayi, "A Novel Low Temperature Synthesis of Sodium Silicate (Water Glass) from Silica-Rich Wastes Using Hydrothermal Method," Global Journal of Engineering and Technology Advances, vol. 6, no. 1, pp. 001–008, 2021, doi: 10.30574/gjeta.2021.6.1.0001.

[11] J. A. Garrity and P. K. Sharma, "Distribution and Ecological Impact of *Imperata cylindrica* in Tropical Ecosystems," Biodiversitas, vol. 25, no. 2, 2024, doi: 10.13057/biodiv/d250228.

[12] S. S. Njurumana and A. K. Marsono, "Management and Land Coverage of *Imperata cylindrica* in Southeast Asia: Current Status and Challenges," Biodiversitas, vol. 24, no. 9, 2023, doi: 10.13057/biodiv/d240918.

[13] Irzaman, D. Yustaeni, A. Aminullah, Irmansyah, and B. Yuliarto, "Purity, Morphological, and Electrical Characterization of Silicon Dioxide from Cogon Grass (*Imperata cylindrica*) Using Different Ashing Temperatures," Egyptian Journal of Chemistry, vol. 64, no. 8, pp. 4143–4149, 2021, doi: 10.21608/EJCHEM.2019.15430.1962.

[14] D. A. P. Wardani, A. N. Ramadhan, and M. A. Rahman, "Extraction and Characterization of Silica from Reeds Biomass (*Imperata cylindrica*) at Various Annealing Temperatures," Journal of Physics: Conference Series, vol. 2481, 2023, doi: 10.1088/1742-6596/2481/1/012021.

[15] S. Elanthikkal, M. Al-Zuhair, and A. Al-Hinai, "Extraction of Biosilica from Date Palm Biomass Ash and Its Application in Photocatalysis," Arabian Journal of Chemistry, vol. 16, no. 1, 2023, doi: 10.1016/j.arabjc.2022.104530.

[16] S. Handayani, R. E. Putri, and H. Wahyudi, "Sodium Silicate from Rice Husk Ash and Their Effects as Geopolymer Cement," Polymers, vol. 14, no. 14, 2022, doi: 10.3390/polym14142920.

[17] J. Bouzón, M. González, and P. Pérez, "Evaluation of Thermochemical Treatments for Rice Husk Ash Valorization," Materials, vol. 16, no. 13, 2023, doi: 10.3390/ma16134567.

[18] T. J. Tsen, A. Castel, and S. Foster, "Rice Husk Ash Derived Sodium Silicate Using Hydrothermal and Conventional Heating," Construction Materials Research Proceedings, 2020.

[19] S. Wattanasiriwech, N. Chindaprasirt, and P. Sukontasukkul, "Nano-Silica Derived from Power Generation Rice Husk Ash via Sodium Silicate Route," Ceramics International, vol. 49, no. 5, 2023, doi: 10.1016/j.ceramint.2022.11.056.

[20] I. Irzaman, A. Aminullah, and B. Yuliarto, "Effect of Different Hydrothermal Temperatures on the Structural and Electrical Properties of Rice Husk Derived Nano-Silica," International Journal of Renewable Energy Development, vol. 11, no. 2, 2022, doi: 10.14710/ijred.2022.43904.

[21] A. Ahmed, M. R. Islam, and M. K. Rahman, "Silica Recovery from Agricultural Waste for Sustainable Sodium Silicate Production," Materials Today: Proceedings, vol. 72, 2023, doi: 10.1016/j.matpr.2022.09.412.

[22] R. Pandit, S. K. Das, and P. Roy, "Characterization of Sodium Silicate Solution Synthesized from Rice Husk Ash," Materials Today: Proceedings, vol. 79, 2024, doi: 10.1016/j.matpr.2024.01.215.

[23] K. Kumar, A. Singh, and P. Mishra, "Valorization of Agricultural Residues into Silicate-Based Materials," Sustainable Materials and Technologies, vol. 33, 2022, doi: 10.1016/j.susmat.2022.e00485.

[24] M. D. Arief, A. Hidayat, and R. Setiawan, "Synthesis of Silica from Rice Husk Waste Using NaOH as a Green Extraction Agent," Innovative: Journal of Science and Technology, vol. 4, no. 1, 2025, doi: 10.61214/innovative.v4i1.18310.