

Extraction and Characterisation of Rice Husk Ash Silicate as an Additive in Geo-Refractory Bricks Production: A Review

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ABSTRACT

Rice husk ash (RHA) is a product of burning rice husk, a waste material from rice production. RHA contains a high amount of amorphous silica, which can be extracted and used as a valuable additive for geo-refractory bricks. Recently, the use of additives in the production of refractory bricks has received considerable attention due to their potential to enhance the properties of these materials. One such material is RHA. This review paper explores the extraction and characterisation of RHA silicate and its application in the production of geo-refractory bricks. Rice Husk (RH) is abundant and often discarded, leading to environmental concerns. The transformation of RH into silicate involves a series of processes, including thermal treatment, hydrothermal treatment, chemical activation, and a combination of thermal and chemical treatments, which enhance its pozzolanic properties. This review presents various methods for extracting RHA silicate, characterising its chemical composition, morphological structure, and evaluating its physical properties. Key findings indicate that the incorporation of RHA silicate improves the mechanical strength, thermal stability, and overall durability of the bricks. This sustainable approach improves the properties of refractory bricks and addresses environmental concerns by reducing agricultural waste. This study reviews the work presented by previous researchers on the extraction and characterisation of RHA silicate and its incorporation into refractory bricks. Additionally, it points out the potential of RHA silicate as an eco-friendly additive, summarises recent research findings, and offers perspectives on the application of RHA as an additive in geo-refractory brick production, thereby encouraging further research and development in this field. Hence, the optimisation of the extraction method for high purity silica needs to be investigated.

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1.0 Introduction

Refractory bricks are essential for high-temperature industrial applications, such as furnaces and kilns, due to their ability to withstand extreme temperatures, thermal shock and corrosive environments while maintaining structural integrity (Birawidha *et al.*, 2025). Traditionally, refractory bricks have been manufactured using natural mineral resources such as clay, bauxite, alumina, and silica (Chima & Nnuka, 2017).

However, increasing emphasis on sustainable production has driven the use of agro-waste as partial substitutes for conventional materials (Novie *et al.*, 2016). This approach aims to reduce production costs, conserve natural resources and minimise environmental impact.

The increasing demand for refractory bricks has prompted researchers to explore alternative sources, driven by the need for more sustainable and cost-effective raw materials. Among these, agricultural waste, such as rice husk (RH), has emerged as a promising source of silica for refractory brick production.

According to Mdoe and Mlay (2021), Tanzania produces about 3.02 million tonnes of rice annually. Since RH constitutes about 20% of the grain's weight, and approximately 20% of the husk after combustion is converted into ash, this production could generate around 700,000 tonnes of RHA each year. However, RH is widely available in many rice-producing regions worldwide but is often discarded, resulting in environmental concerns. Studies have shown that amorphous silica is formed at temperatures below 800°C, while higher temperatures promote the development of crystalline phases (Mboya *et al.*, 2017; Fusinato *et al.*, 2023).

Moreover, previous studies by Erhuanga and Fadairo (2025), Zharmenov *et al.* (2022), Onyia and Idenyi (2024), Ullal *et al.* (2022), Nayak and Datta (2021), and Olusola & Omowumi (2024) have demonstrated that RH has a rich source of silica which can be extracted and potentially used as an additive in the production of refractory bricks.

Although several studies, Mustapha *et al.* (2025), Jechira *et al.* (2026), and Olusola and Omowumi (2024), have reported that RHA is suitable for

incorporation into geo-bricks, an optimised extraction method is still required to obtain high-purity silica.

Despite the growing interest in RHA as a renewable source of silica, a standardised approach for the production, characterisation and selection of RHA-derived silicate as an additive in the manufacture of geo-refractory bricks has yet to be established.

This paper aims to review current research on the extraction and characterisation of RHA and its application as an additive in the production of geo-refractory bricks. The review examines the key steps involved in the extraction process, the physicochemical properties of the extracted silica, and the impact of incorporating RHA in the production of refractory bricks. The findings provide valuable insights into the potential of RHA as a sustainable additive for enhancing the production of geo-refractory bricks and highlight its role in developing environmentally friendly refractory materials.

2.0 Related Studies

In recent years, several studies have been extensively conducted on the incorporation of RHA in construction materials.

Phonphuak *et al.* (2019) investigated the physical and mechanical properties of fired clay bricks with RH. The study revealed that apparent porosity and water absorption increased with increasing RH content but decreased as the firing temperature increased. In contrast, the compressive strength of the bricks decreased with an increase in RHA content. However, the highest compressive strength of 16 MPa was achieved with the addition of 2.5% RH, which was considered adequate according to ASTM standards. The study concluded that RH can be used in the production of lightweight fired clay bricks.

The influence of RHA as an additive in brick production was examined by Damanhuri *et al.* (2020), evaluating clay replacement levels of 0%, 5%, 10%, 15% and 20% RHA. It was found that the excessive addition of RHA reduced the compressive strength of the bricks while increasing water absorption. The study concluded that the addition of 10% wt RHA produced the optimum brick properties, achieving a

compressive strength of 6.8 MPa and water absorption of 16.30%.

Similarly, Ketov *et al.* (2021) studied the recycling of RHA for the production of resistant, lightweight, and environmentally friendly fired bricks. The study demonstrated that the incorporation of RHA resulted in the formation of cellular brick structures with improved thermal insulation properties. The findings indicate that RHA has significant potential as a sustainable additive for the development of lightweight and energy-efficient brick materials.

Furthermore, Onyia and Idenyi (2024) investigated the refractory potential of clay enhanced with RHA as an additive. Their findings revealed that firing shrinkage decreased with increasing RHA content, whereas total shrinkage increased. The authors suggested that the addition of RHA modifies the physical properties of clay, contributing to the development of lightweight refractory materials.

Oe and Mbakaan (2022) evaluated the performance of RHA-based thermal insulators for heat energy-saving applications. The findings showed that RHA possesses a high silica content and low thermal conductivity, which enhance the mechanical and physical properties of thermal insulating materials. The study further revealed the potential of RHA as a sustainable material for developing efficient thermal insulation products.

3.0 Extraction of Rice Husk Ash Silicate

The literature review identified several approaches for the extraction of silica from RHA, including thermal treatment, chemical treatment, and a combination of both methods. The most commonly reported techniques are summarised below:

- i. Thermal treatment: RH is subjected to high-temperature calcination (600-800°C) to burn off organic matter and produce amorphous silica.
- ii. Chemical treatment: RH is treated with acids (e.g., hydrochloric acid (HCl) and sulphuric acid) or bases (e.g., sodium hydroxide (NaOH)) to eliminate impurities and facilitate silica dissolution, followed by precipitation to recover the final products.
- iii. Thermal-chemical treatment: a combination of chemical purification and calcination is

employed, where RH is first subjected to chemical treatment to remove impurities, followed by thermal processing to enhance silica purity.

Daulay *et al.* (2021) assessed the extraction of silicate from RHA using NaOH leaching, followed by combustion of RH at varying temperatures (600°C, 700°C, 800°C and 900°C). The study illustrated that silica powders produced at 600°C, 700°C, and 800°C exhibited no significant differences in composition. However, the material obtained at 600°C recorded the highest silica content, with SiO₂ and Si concentrations of 44.4% and 24.3%, respectively.

A different approach was reported by Azat *et al.* (2019). The study assessed the extraction of silica from RH through acid leaching. RH was treated with a 2 M HCl solution before calcination at 600°C to produce high-purity white silica with a high specific surface area and low impurity content. The study established that acid leaching, followed by controlled calcination, yielded amorphous silica with a purity ranging from 98.2% to 99.7% and a specific surface area between 120 and 980 m²g⁻¹.

Another extraction technique was reported by Setyawan *et al.* (2019), using technical-grade solvents to extract silica from RHA. The highest average silica yield was obtained with a 1N NaOH solution at a solid-to-liquid ratio of 1:6.

Further studies by Ajeel *et al.* (2020) and Kalapathy *et al.* (2003) examined the extraction of silica from RHA using alkaline and acid leaching techniques. The results indicated that amorphous silica could be successfully extracted using NaOH and a combination of HCL and NaOH. Struct (2019) and Tufaner *et al.* (2019) investigated the preparation of amorphous silica from RHA, a renewable agricultural waste, via calcination combined with chemical activation. In the studies, NaOH and potassium hydroxide (KOH) were used as activation agents. The findings highlighted that calcination at 750°C for 2 hours, with an optimum alkali-to-RHA ratio of 4:1, produced amorphous silica. Furthermore, NaOH as an activating agent was found to be more effective than KOH.

Following the application of different alkaline activators, Zuwana *et al.* (2023) explored the use of KOH as an alternative agent for extracting silica (SiO₂) from RHA. The results showed that the SiO₂

obtained increased from 2.85% to 27.42% as KOH concentration increased from 1N to 3N, with intermediate yields of 4.63%, 7.32% and 15.63% obtained at 1.5N, 2N and 2.5N, respectively. These results indicated that increasing KOH

concentration enhanced silica extraction from RHA.

Table 1 below provides a summary of researchers who studied the extraction of silicate from RHA:

Table 1

Extraction of RHA by Different Techniques

Source	Extraction Methods	Findings	Application
Daulay <i>et al.</i> , (2021)	RH was burned at different temperatures(600,700,800 and 900°C); followed by leaching with 10% NaOH at 90°C at 240rpm for 2 hours. The extracted solution was neutralised with HCL until pH 7, then dried to obtain silica.	Amorphous silica was obtained, with the highest SiO ₂ and Si contents of 44.4% and 24.3% respectively	
Ajeel <i>et al.</i> , (2020a) Ajeel <i>et al.</i> , (2020b)	RH (100g) was leached with 3N HCL(500ml) at 80°C for 4hrs. The residue was washed, dried at 100°C for 6 hours, calcinated at 700°C, and further treated with NaOH leaching at 80°C. The material was calcinated at 700°C followed by NaOH leaching at 80°C	Amorphous silica with a 99.714% was obtained	
Azat <i>et al.</i> , (2019),	RHA was calcined at 600°C. The white RHAs was treated with 100ml of 2M NaOH at 90°C to remove insoluble residues. Sodium silicate was converted into insoluble silica using 2M HCL under continuous stirring, followed by washing and drying at 105°C for 4 hours.	Amorphous silica with a purity of 98.2%-99.7% and surface area up to 980m ² /g was obtained	
Setyawan <i>et al.</i> , (2019)	RHA was mixed with NaOH solutions(0.50N, 0.75N and 1N) at various ratio (1:4, 1:5 and 1:6), then heated at 80°C for 1 hr, filtered, and titrated with 1N HCL. The resulting silica gel was washed, filtered, and dried 70°C for 22 hours, then grounded into silica powder. Silica gel obtained was added with distilled water and broken to form slurry then dried at 70°C for 22hrs and grinded to form silica powder.	A maximum silica yield of 62.83% was obtained at a ratio of 1:6.	Fertilisers raw materials
Das, (2020)	Precipitation of silica was carried out at 500, 600, 650, 700 and 750°C using NaOH concentrations of 5%, 10%, 15% and 20%.	Silica content of approximately 90% SiO ₂ was obtained	Wastewater treatment, building materials, catalyst compound etc.
Kalapathy <i>et al.</i> , (2003)	RHA (100g) was reacted with 1M NaOH (500ml) and boiled at 100°C for 1 hour to produce Sodium Silicate. The solution was filtered through Whatman No. 41 to remove carbon residue and processed into silicate blocks.	Silicate blocks with thermal insulation properties were produced.	Thermal insulator
Jonathan <i>et al.</i> , (2020)	RH was washed, dried at 105°C, and calcined in a muffle furnace at 700°C for 3 hours to produce furnace rice husk ash (FRHA). On open air burning was also performed to produce Open air rice husk ash (ORHA)	SiO ₂ contents of 94% and 95% were obtained from FRHA and ORHA respectively. ORHA contained amorphous silica, while FRHA contained crystalline silica.	
Zuwanna <i>et al.</i> , (2023)	RHA was dried at 100°C, crushed with mortar and pestle then sieved with 250 µm. A 250g of RHA sample were extracted with various concentrations (1N, 1.5N, 2N, 2.5N and 3N) of 200ml, KOH solution and heated at 80°C for 1hr and stirred at a	The highest SiO ₂ (27.42%) was obtained at 3N KOH.	Filler agent for bio composite film.

Source	Extraction Methods	Findings	Application
	rate of 400rpm. Thereafter the solution was filtered and cooled at room temperature. The solution was titrated with 3N HCL at a constant stirring up to 7ph. The precipitates were filtered, dried for 12 hrs at 120°C to remove moisture and form xerogel. The resultant xerogel was rinsed with 100ml distilled water, stirred for 15m at 80°C. The mixture was filtered and dried at 120°C for 4h followed by crushed.		

4.0 Characterisation of Rice Husk Ash (RHA)

The characterisation of the extracted RHA silicate revealed that it is primarily composed of amorphous silica, with a high purity (typically >90%) and a surface area ranging from 150 to 980m²/g. The silica particles exhibited a porous and irregular morphology, which could potentially enhance their reactivity and integration into refractory brick formulation.

Bhardwaj *et al.* (2017) investigated the preparation and characterisation of clay-bonded silica refractories by utilising agricultural wastes. The study reports that RHA contains more than 90% SiO₂, a silica content comparable to that in quartz, indicating suitability as a refractory raw material. Microstructure analysis (SEM) of RHA calcined at 600°C revealed a porous microstructure with a high specific surface area, which enhances active surface activity during sintering and promotes improved phase formation. In addition, the X-Ray Diffraction (XRD) analysis confirmed the presence of predominantly amorphous silica through the absence of sharp diffraction peaks.

Similarly, Tufaner *et al.* (2019) characterised silica from renewable agricultural by-products to evaluate the physicochemical properties. Using Fourier transform infrared (FTIR) spectroscopy, characteristic absorption bands at 1050 and 789 cm⁻¹ were identified, corresponding to the asymmetric and symmetric stretching vibrations of the Si-O-Si bonds, respectively. The absence of absorption peaks associated with other RHA components indicated that impurities were

present in low amounts. Furthermore, XRD analysis showed characteristic diffraction peaks corresponding to crystalline silica following calcination at 700°C for 6 hrs, while SEM revealed a microstructure with low porosity and relatively low specific surface area.

Additionally, Salim *et al.* (2023) focused on the characterisation of high-purity silica synthesised from RHA using solvent-thermal treatments acid leaching at different HCL concentrations. The key finding was that acid leaching with 1M HCL produced silica with a purity of 99.99%. The study concluded that a combination of solvent-thermal treatment and acid leaching is an effective approach for producing high-purity silica with a small particle size and high specific surface area. The physicochemical properties of the synthesised silica were characterised using XRF, XRD, SEM and FTIR methods.

In addition, another study by Bouzón *et al.* (2023) used thermochemical treatments for the valorisations of RHA as a source of silica for geopolymer production. XRF analysis revealed that the RHA contained 85.58% SiO₂. The XRD spectrum of RHA indicated characteristic diffraction peaks at 2θ, indicating the presence of amorphous silica, while SEM showed irregularly shaped and porous particles with a rigid silica skeleton that remained intact after combustion. The findings revealed that thermochemical treatment effectively preserved the silica structure, making RHA a promising precursor for geopolymer applications.

Table 2 shows the different characterisation methods and the amount of silica obtained from various researchers:

Table 2
Characterisation of RHA Silicate by Different Technique

Source	Objectives	Characterisation			
		XRF		XRD	
					SEM
Jonathan <i>et al.</i> , (2020)	Characterised the elemental composition, crystallinity, functional bonds present, and morphology of RHA obtained through two methods; calcination of rice husks in muffle	SiO ₂ contents 95.45% and 94.85% for ORHA		SiO ₂ was crystalline highest peak 21.8° at 700°C whereas	RHA particles exhibited clustered morphology

Source	Objectives	Characterisation		
		XRF	XRD	SEM
	furnace (FRHA) at 700°C and open air burning (ORHA) at uncontrolled temperature.	and FRHA respectively.	ORHA showed an amorphous silica structure	
Rivas <i>et al.</i>, (n.d.)	Prepared RHA using two approaches: washing followed by calcination at 650°C and acid purification using 1N HCL followed by calcination.	SiO ₂ contents 87.39% and 96.94% were obtained from untreated and acid-treated samples respectively.	The samples exhibited amorphous silica after calcination at 650°C for 3 hours with broad amplitude in the 2 θ range.	The RHA retained the original RH morphology, characterised by a rich silicon skeletal structure
Salim <i>et al.</i>, (2023)	Characterised high purity silica synthesised from RHA using solvent-thermal treatments followed by acid leaching at different HCL concentration.	High purity with 99.99% SiO ₂ was obtained.	The synthesised silica exhibited an amorphous structure	Untreated RHA has no clear boundary; this is due to present of lignocellulosic component and treated RHA has the spherical shape due to the decomposition of lignocellulosic component.
Rojas <i>et al.</i>, (2019)	Investigated the effect of thermal treatment and acid leaching on silica extraction from RHA.	SiO ₂ contents of 93.4% and 98.47% were obtained before and after chemical treatment respectively.	Amorphous silica	Silicon oxide was identified as the principal structural phase of nanoparticles. where the predominant peak occurred at 22.09 degrees (2 θ).
Bhardwaj <i>et al.</i>, (2017)	Prepared clay bonded silica refractories utilising agriculture waste	RHA contained more than 90% SiO ₂ almost similar to Quartz silica content	The absence of sharp diffraction peaks confirmed the presence of amorphous silica, which is more reactive than the crystalline silica.	SEM revealed porous internal structure, contributing to a high specific surface area, and active surface area during sintering.
Oe & Mbakaan, (2022)	Prepared a thermal insulator using nano silica-based ash generated from chemically treated RH	SiO ₂ was identified as major compound, with a silica yield of 99.2% due to acid pre-treatments.	A broad diffraction peak between 15-30° with a maximum at 2 θ 26.58°, which indicated amorphous silica.	SEM image revealed nano sized irregular shaped particles
Ajeel <i>et al.</i>, (2021)	Produced high purity nano silica from agricultural wastes of rice husk by using developed chemical extraction techniques.	High purity amorphous silica 98.4% to 99.9% was obtained at 700°C	A broad peak was noticed corresponding to amorphous silica. Further the XRD confirms that changing of NaOH concentration affected the curves of Nano silica.	

5.0 Application of Rice Husk Ash into Refractory Bricks

Several studies have investigated the incorporation of rice husk ash silicate as an additive in the production of geo-refractory bricks. The typical replacement levels of rice husk silicate in the brick formulation ranged from 5 to 30 wt%. The key findings from these studies are summarised below:

Eliche-Quesada *et al.* (2017) evaluated the possibility of utilising RHA and wood ash (WA) (10-30 wt %) in fired clay bricks and reported significant effects on their physical and mechanical properties. The addition of RHA and WA significantly increased linear shrinkage, porosity, and water absorption, with maximum porosity values of 10.8% vol% and 7.3 vol% for RHA and WA, respectively. Water absorption also increased to 32.9% for RHA and 21.2% for WA. On the other hand, bulk density decreased up to 25.1% and 9.8% by the addition of RHA- and WA-containing bricks, respectively, while the compressive strength was reduced to 13.5 and 17.5 MPa for 30 wt% of RHA bricks fired at 900 and 1000°C, respectively.

Also, Kazmi *et al.* (2018) reported the thermal performance of burnt clay bricks incorporating sugarcane bagasse ash (SBA) and RHA as a partial replacement for clay (5, 10, and 15 wt%). The physico-mechanical and thermal properties of the brick samples were investigated after burning at 800°C. The study reported that the addition of SBA and RHA produced lightweight bricks with densities of 1060 kg/m³ and 1130 kg/m³, respectively, while reducing production cost. Moreover, increasing the SBA and RHA content decreased the compressive strength (up to 5.53 MPa), flexural strength (up to 0.83 MPa) and thermal conductivity (up to 0.37 W/Mk). In contrast, porosity increased to 40%, resulting in higher water absorption of up to 23.86%. Despite these changes, the produced brick satisfied the minimum requirement specified by ASTM C67.

A related study by De Silva and Perera (2018) illustrated the potential use of RHA as a partial replacement for clay (0-10 wt%) in the manufacture of fired clay bricks. The results indicated that RHA improved brick properties, with a maximum compressive strength of 3.55

MPa (32.7%) higher than that of conventional fired clay brick, and a water absorption of 19% at 4 wt% RHA was obtained. In addition, the density decreased from approximately 1450 kg/m³ at 0% RHA to about 1220 kg/m³ at 10% RHA. The study found that 4% RHA was the optimum replacement level for producing fired clay bricks.

Similarly, Sorna *et al.* (2016) examined the incorporation of RHA (5-20% vol%) and brick waste (BW, 5-10 vol%) as a partial replacement for clay in the production of construction bricks at 1000°C. The study indicated that the developed bricks decreased in dry shrinkage (5.12-1.5%), firing shrinkage (4.9-1.12%), apparent density (1730-1530 kg/m³), and cold crushing strength (17.5-12.5 MPa). Therefore, RHA and BW can serve as alternative raw materials for producing fired clay bricks with significant properties and contribute to sustainable construction.

Sobrosa *et al.* (2017) demonstrated the incorporation of RHA (5, 10, and 20% vol.) as a partial replacement of kaolin clay in the production of refractory ceramics. It indicated that the addition of 10 vol% RHA produced refractory materials with improved mechanical and thermomechanical properties, enhancing mechanical strength without decreasing resistance to thermal shock. The findings indicated that an optimum RHA content can improve refractory performance while maintaining thermal stability.

Moreover, Hwang and Huynh (2015) evaluated the engineering performance and microstructural characterisation of eco-friendly construction bricks produced using a binder material made from a mixture of class F fly ash (FA) and residual RHA. The properties of the bricks conform to the Vietnamese standard. Therefore, FA and RHA are potential candidate materials for producing eco-friendly construction bricks using geopolymerisation technology.

6.0 Limitations and Challenges

The review also identified some limitations and challenges associated with the use of RHA in refractory bricks:

- i. Compatibility issues: The effective integration of rice husk ash silicate into the refractory brick formulation may require

careful optimisation of the particle size, morphology, and surface properties to ensure satisfactory compatibility with other raw materials.

- ii. Scalability concerns: The scalability of the extraction and processing of RHA may pose challenges, particularly in ensuring consistent quality and availability of the raw material for large-scale production of refractory bricks.
- iii. Potential impurities: Depending on the extraction method and the source of the RHA, the silica may contain residual impurities that could affect the performance and quality of the final refractory bricks.
- iv. Optimisation: More work is required to optimise mix design for different application requirements and to ensure long-term durability under operational conditions.

Overall, the review highlights the promising potential of RHA as a sustainable additive for refractory bricks, with the ability to enhance thermal and mechanical properties. However, further research is needed to address the identified limitations and challenges to fully realise the benefits of these agricultural waste-derived materials in the refractory industry.

7.0 Conclusion

The comprehensive review of the existing literature on the extraction and characterisation of silica from RHA, as well as its incorporation into the production of refractory bricks, has yielded valuable insights and identified several key findings:

The review has demonstrated that RH, an abundant agricultural waste product, can be effectively utilised as a source of high-purity amorphous silica through various extraction methods, including thermal treatment, chemical treatment, and a combination of both. The characterisation of the extracted RHA silicate has revealed its desirable physicochemical and thermal properties, making it a promising additive for the refractory industry.

The incorporation of RHA silicate into the formulation of refractory bricks has been extensively investigated, and the results indicate

that it can significantly enhance the thermal and mechanical properties of the final products. The addition of RHA silicate has been shown to improve the thermal resistance, refractoriness, and compressive strength of the refractory bricks, while also contributing to a more homogeneous and denser microstructure.

Furthermore, the utilisation of RHA as a raw material for refractory bricks offers potential cost and environmental benefits, as it provides a sustainable solution for the valorisation of agricultural waste. This aligns with the growing emphasis on the development of eco-friendly and resource-efficient construction materials.

However, the review has also identified some limitations and challenges associated with the use of RHA silicate in refractory bricks. These include potential compatibility issues, concerns about scalability and consistent availability of the raw material, and the need to ensure the purity and quality of the extracted silica.

To fully unlock the benefit of RHA silicate as a sustainable additive for refractory bricks, further research is recommended in the following areas:

- i. Optimisation of the extraction and processing techniques to enhance the quality and consistency of the RHA silicate.
- ii. Detailed investigation of the compatibility and integration mechanisms between RHA silicate and other raw materials in the refractory brick formulation.
- iii. Pilot-scale production and comprehensive evaluation of the performance and durability of refractory bricks containing RHA silicate under real-world conditions.
- iv. Techno-economic analysis and life cycle assessment to understand the viability and environmental impact of incorporating RHA silicate in the refractory industries

By addressing these research gaps, the potential of RHA as a viable and sustainable additive for refractory bricks can be further realised, contributing to the development of more eco-friendly and high-performance construction materials.

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10.0 Declaration of Conflict of Interest

The authors declare no conflicts of interest.

11.0 References

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