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A Comprehensive Review of Rice Husk Derived Silica As Nano Filler (A review of literature)

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Abstract:
Nowadays, the entire globe is suffering from two types of problems: excess waste production and a scarcity of virgin resources. Utilizing wastes in the primary industrial sector is one way for addressing these concerns from the viewpoints of developing nations' ecosystems, energy demands, and economy. Natural fillers such as bamboo, rice husk, pistachio shells, and coir fiber have been reported to be efficient natural fillers. When natural materials are used as reinforcing materials, they offer advantages such as cost-effectiveness, high density, renewability, and a high degree of flexibility in the task, as well as a healthier working environment.

Keywords: Nano filler, silica, Rice Husk.

Introduction:

Nanotechnology is concerned with the creation of exclusive tiny particles. These particles have revolutionized sectors like as technology, health, and consumer items. Silica nanoparticles, which have found significant usage in the industrial, food, and agricultural areas such example of nanotechnology. In general, nanoparticles were created via physical and chemical techniques. Ultrasonic shot peeling, extreme deformation of plastic, gas condensation, and pyrolysis are some of the physical handles employed (Yasser, 2017). Those methods are frequently employed to create metallic nanoparticles. Pulse electrodeposition, chemical precipitation, chemical vapor condensation, chemical and phytochemical reduction, and electrochemical processes are examples of chemical procedures (Azat, 2020) (Rodríguez-Sánchez. 2000).

Chemical operations, taken as a whole, include the usage of several harmful and hazardous compounds that have a negative impact on the biotic environment. This paved the way for the development of nanotechnology, which synthesizes nanoparticles utilizing environmentally friendly methods and bio-agents. Green nanotechnology, in general, uses microorganisms (fungi, bacteria, algae) and organic substrates to produce nanoparticles (plant extracts). These solutions are not only environmentally friendly, but also highly cost effective (Sharma, 2009) (Shankar,2005). To create silica nanoparticles, silicon alkoxides are often dissolved in alcohol. Ammonia is employed as a catalyst in a number of applications, and the range of nanoparticles in size from 50 nm to 1 m. Metal oxides are essential in a range of nanomaterial research disciplines. The size of the oxide particles in a substance affects the structure, size of particle, and other properties (Thomas, 2018) (Zheng, 2021).

Similarly, surface features are crucial since they have a large influence in solid-liquid or solid-gas processes (Nasser, 2023). Nanoparticles such as ZrO2, CeO2, TiO, and TiO2 have been created and can be used in industries such as the sensors, coating, agrochemicals, anti-corrosives, fuel cells, and catalysts (Ndolomingo, 2020) (Gao, 2021). For instance, iron oxide NPs are employed in applications including the separation of cell components, medication delivery, nano-coating, and food packaging because they have significant magnetic properties (Iriarte-Mesa, 2020) (Ndolomingo, 2020).

One of the most abundant minerals on the planet is silica (SiO2) (Goodman, 2020). Silica nanoparticles (SNPs) have captured the interest of the research community because to their diverse physiochemical properties (Khan, 2020) Depending on the pore size, the particles may be categorized as mesoporous or nanoporous (Narayan, 2018). The size of the particles can be altered by modifying the surfactant mix during synthesis (Liou, 2011). Because silica nanoparticles are hydrophobic, have a high surface area and pore volume, and are biocompatible, they have a wide range of applications (Wang, 2015) (Li Z, 2012).

Recently, scientists have used silicon nanoparticles (SNPs) to carry a variety of payloads, including medicines and macromolecules (Ahmed, 2023) (Abd Alrazaq, 2023). silica nanoparticles use in scientific fields, involving biomedicine, personal care items, insecticides, adsorption, semiconductors, and ceramics during oil exploration, transportation, and storage usage of silica nanoparticles to absorb oil spills is more recent (Jeelani, 2020) (Bera, 2020) (Hadia, 2021).

It can be expensive and challenging to manage the research being done to investigate and utilize new silica nanoparticle applications. For instance, in a reverse microemulsion, water is used to dissolve the surfactant molecules, resulting in the formation of spherical micelles. Although this method is efficient, it is expensive and challenging to separate the surfactants in the finished goods (Narayan, 2018).

Despite this, the nanoparticles produced in this manner were effectively employed as a coating to attach functional groups Chemical vapor condensation is another prominent method for producing silica nanoparticles (CVC) (Liu, 2010) (Liberman, 2014) (Silva, 2004) .

Chemical nanotechnologies are presently quickly advancing in line with the growing human need for new nanotechnologies "Nanoscience" is defined as the branch of science dealing with the characterisation and research of nanomaterials, as well as the determination of their physical and chemical characteristics between 1-100 nanometers. As a result, the area of research places a high value on the development of nanotechnologies, and their use is critical in a variety of human activities (Kareem, 2022) (Salman, 2017) (Naji, 2020).

Recycling waste products of various agricultural and industrial efforts attain wide attention in technology, economic, and scientific research in recent years, Rice husk; is a by-product of the milling of rice whereas rice husk ash is produced by burning RH. Therefore, RH is recycled by heating it during the production of energy-yielding RHA which is composed of amorphous silica (Hossain, 2018).

While organic substances comprise 70–80% of Rice Husk, and the mineral components comprise the residual 20–30%. The minerals include silica, alkalis, and others in small elements (Sarangi, 2009), The porous nature of amorphous Nanoparticles of silica are what creates the three-dimensional space. It is possible to modify the porosity to contain either big or tiny nanomaterials. Additionally, because silica nanoparticles are almost transparent, they are not expected to absorb near-infrared light. For biomedical research, the silica matrices are harmless and biocompatible (Pode, 2016) The chemical composition of rice husk ash (RHA) can vary according to the geographical location and climatic conditions, type of soils, fertilizers, and the paddy (Sankar, 2016) RHA characteristics reliant to the ecological environments and the applied burning procedures, RHA contains a huge content of amorphous silica, which has extensive uses in construction and chemicals industries (Gonzalves, 2007).

Bio fibers derived from agricultural byproducts for industrial and biomedical use:

The three primary components of natural fibers are cellulose, hemicellulose and lignin Natural fibers (obtained from plants) may be categorized into four groups Classification of vegetable sources based on the parts from which they are derived (Soltani, 2015) :

1. Fruit: These fibers are removed from the plant's fruit, are light, and transport the seeds by wind.
2. Bast: which is present in the plant's stems and provides strength. Typically, they extend to the entire length of the stem and believe to be consequently quite long.
3. Leaf: fibers are removed from the leaves; they are robust and serve as a plant's mode of transport.
4. Stalk: These fibers are made of a narrow or elongated structure that supports an organ or other body component.

Rice, RH, and RHA:

Rice husks are the natural sheaths covering the rice grains during their growing season; during the milling of rice, these RH are removed; they have no interest commercially; despite that, they can be made advantageous using different thermochemical conversion procedures, Rice husk (RH) as a plentiful bio waste with poor combustion value and environmental harm might raise the question of its sustainable use (Pode, 2016).

The Rice Husk is the paddy grain's outermost layer, which is removed from the rice grains after milling. The chemical composition of RH varies from sample to sample because of variances in paddy type, crop year, climate, and geographical factors (Sanka , 2016).

Rice Husk is mainly made up of lignin (20–30%) SiO_2 (15–20%) and extracts (2–5%) of holo cellulose (55–65%) which may be considered a natural organic-inorganic composite (Shen,2018; Zhao & Li,2016) During the burning process L-arabinose lignin cellulose hemicellulose (Shen, 2018).

Recycling agricultural and industrial byproducts has attracted significant interest in technological, economic, and scientific studies in recent years. Rice husk is a rice milling byproduct while rice husk ash is created from the combustion of RH Therefore RH is recycled by heating it during energy generation to produce amorphous silica-based RHA. 85 to 95 percent of Rice husk ash is amorphous silica. RHA has been exploited in several fields for the production of cement silicates zeolites and nanocomposite (Hossain, 2018).

While organic substances comprise 70–80% of Rice Husk the mineral components comprise 20–30% residual The minerals include silica alkalis and other minor elements (Sarangi, 2009).

The three-dimensional space is provided by the tremendous amorphous silica nanoparticles considered porous The porosity may be adjusted to contain either giant or tiny molecules of nanomaterials. Additionally, since silica nanoparticles are almost transparent, they are not expected to absorb near-infrared light For biomedical research, silica matrices are harmless and biocompatible (Sharma, 2016).

According to the geographic location, meteorological circumstances type of soils fertilizers, and paddy rice husk ash's (RHA) chemical composition might change [33], RHA characteristics reliant on the ecological environments and the applied burning procedures RHA contains a considerable content of amorphous silica, which has extensive uses in construction and chemicals industries (Gonzalves, 2007).

The structural transformations of RH silica rely on combustion conditions such as time temperature and acids concentrations. The transition from amorphous to crystalline ash begins at around 800°C and is completed at about 900°C Amorphous ash is created between 550°C and 800°C, while crystalline ash is formed at higher temperatures. It is important to note that none of the combustion procedures used to burn rice husks reaches the melting temperature of the husks which is 1440 °C (Pode, 2016).

Synthesis methods of silica extraction:

Chemical approaches (acid/alkali leaching and post-heat treatment) as well as non-isothermal, fluidized bed, carbonization and combustion, pressured hot water, microwave hydrothermal, and precipitation may also be used to create nanostructured SiO2 from RHA. The chemical process, which consists of simple acid leaching and post-annealing, is one of the easiest and most effective ways to create ultrafine SiO2 nano powder from RHA (Muramatsu, 2014).

RHS structural changes depend on combustion parameters such as time, temperature, and acid concentrations. The transition from amorphous to crystalline ash begins at around 800°C and is completed at about 900°C. Amorphous ash is created between 550°C and 800°C, while crystalline ash is formed at higher temperatures. It is important to note that none of the combustion procedures used to burn rice husks reach the melting temperature of the husks, which is 1440 °C (Pode, 2016).

1. Combustion method:

This procedure is applied in industrial and environmental activities it might be accomplished in opened-fire stoves or suspension-fired boilers. Oxygen within the material has an oxidizing effect during the burning (Witchakorn, 2004).

RH incineration is followed by the generation of approximately 20% wt. of ash known as Rice hush ashes This RHA is composed of silica in a percentage of more than 85 wt.% (Bhardwaj, 2017).

manufactured amorphous silica with high purity through the combustion method after treatment of RH with acids. Due to acid leaching of Rice husk, the concentration of pure particles of silica increased from 95% to about 99%. Hence, the acid treatment suggested an increase in the specific surface area. utilized the same combustion method procedure to produce silica powder in nanoparticles from RH (Bakar, 2016).

Azmi et al. in 2016 stated that the rice husk underwent decomposition due to heating under temperatures between 700°C and 1000°C to yield powder mainly composed of silica (SiO2) (Azmi, 2016).

The raw material was meticulously washed using distilled water, followed by drying inside the kiln at around 60 °C Subsequently, the quantity of 100 gr. Samples were exposed to bleaching for 16 h at room temperature in an HCl solution (1.5 L) to diminish the impurities, wash with distilled water, and dried. For combustion of the organic components (calcination), bleached sample, in percentages of 20 gr, engaged in a graphite container for calcination inside a kiln at around 650°C for 3 hours, attaining RHA rich in amorphous silica (Rivas, 2018).

2.Chemical method:

Silica in nanoparticles and high-purity has a broad application in various fields like electronic components pharmaceuticals drug delivery systems dyes, catalysts, and adsorbent materials. Therefore, the mandate for pure silica is growing. RHA manufactured in combustion technique without acid treatment comprises SiO_2 in a concentration of less than 95% and diverse alkali oxides and impurities The SiO_2 constituents can be increased to higher than 99% with the suitable acid treatment of RH/RHA. Therefore, different authors have assumed various Chemical procedures to achieve silica with high purity and nanoparticles (Hao,2006).

In 2013, Zulkifli et al. produced silica powder from RH using the sol-gel route by using precipitating agents such as phosphoric acid. They stated that the synthesized powder has excellent physical and chemical characteristics, and concluded that globular silica particles synthesized from RH through a sodium silicate predecessor derivative of rice husk. By directing reaction circumstances such as adding water PH altering (phosphoric acid) the ethanol addition, silica is obtained with a high specific surface area and spherical morphology. This route is economic and lacks environmental hazards produced by silica particles with appropriate features (Zulkifli, 2013).

Song et al., in 2018, manufactured silica from RH according to Taguchi's approach; it involves two steps: the first is represented by the production of ash from RH while the second is the production of silica powder from this rice husk ash (Song, 2018).

3. Sol-Gel Method:

Sol-gel procedure is a simple non-hazardous manufacturing technique for producing ceramic materials with a sol-gel transformation at a relatively low temperature This procedure synthesizes coatings with personalized microstructure and porous scaffold Sol is a stable colloidal suspension of particles; during transformation, condensation reactions and drying turn the sol into a rigid, porous mass the procedure primarily depends on Hydrolysis with metallic oxides condensation reaction (. Gshalaev, 2012).

The sol-gel procedure is divided into five steps: precursors solution, gelation aging followed by dryness and densification. The synthesis of silica glass is initiated by mixing a suitable alkoxide with water and ethanol as solvent to form a sol. Then silanol groups Si-OH formed by the action of Hydrolysis. These intermediate species react further to develop siloxane Si-O-Si groups (Moheet, 2020).

Moheet et al., in 2019, confirmed the production success of more minor, spherical silica particles made using the sol-gel technique and elongated Nano-HA. They concluded that Nano Hydroxyapatite-Silica-GIC could alter the properties of glass ionomer dental restorative materials (Moheet, 2020).

Bacterial Compatibility/Biogenic Silica Toxicity:

Electronics and medical treatment currently make use of silica SiO2. In addition, silica may be manufactured from various natural resources including quartz sands protozoan sponges, and higher plants Rice byproducts may be used to create biogenic silica (Sharma, 2019).

For biogenic silica, RH is among the greenest materials available. RH has an organic Chemical content in percentages of lignin 22% hemicellulose 20% cellulose 38% and an inorganic chemical composition (SiO2) of 20% (Larichev, 2015).

Silica nanoparticles have been shown by Cappelletti et al., 2014 to have antibacterial characteristics and to be less harmful to cell types. Additionally, biologically generated SiO2 nanoparticles often exhibit biocompatibility with human cell lines (Capeletti, 2014).

The properties of SiO2 nanoparticles are better-understood thanks to their extraction from RHA (Alshatwi, 2015).

SiO_2 silica microstructure, bacterial compatibility, and toxicity are all predicted to differ depending on the material's geographic origin, RHA type, and nanoparticle size The demands of potential upcoming applications have yet to be successfully met by uniformly dispersed spherical SiO2 Nanoparticles (Sharma,2019).

Application rice husk silica:

The world is facing two new problems: there need to be more new resources for bioactive materials, and there need to be more places to put the waste. Using the extra waste in regular production can solve these problems. Rice husk (RH) has much amorphous silica so it can be used in many different fields such as electronics chemicals building materials and ceramics. So, different studies were done to find how rice husk could be helpful (Kareem, 2022).

Many authors have talked about how rice husk can be used in many scientific fields and how rice husk silica can be used to make new silicon, non-oxide ceramics, and silica nanoparticles (Gonzalves, 2007).

RH has a high calorific value which means it could be used as firewood to create energy through combustion This burning creates another waste product that makes the environment dirty: RHA, which makes up 25% of RH (Kishore, 2011).

Silica is an essential raw material for many industrial uses such as ceramics Due to its high reactivity, there are more and more uses for amorphous silica today. Fused silica is the only way that amorphous silica can be used in industry. Rice husk and its ash are other sources of active amorphous silica that can be used repeatedly (Hossain, 2018).

RH is not perfect for nutrition so it is rarely used as animal food Traditionally it has been used as a fertilizer, in rugs for breeding animals, as fuel for cooking, and in landfills or as paving Other good uses of Rice Husk (RH) include making composites partition boards and biochar (Azat, 2019).

many researchers have shown an interest in applying RH silica in several fields In the past few decades some applications of silica derived from Rice husk (Hossain, 2018).

1. Applications in Water Purification:

Previously, silica SiO_2 nanoparticles have been employed in research to remove heavy metals from aqueous solutions, allowing users to clean up industrial waste (Akhter, 2021) SNPs have also been discovered that minimize or remove the requirement for biological oxygen. This type of BOD activity outperforms previous, non-SNP-based approaches Applications in Water Purification (Sibag, 2015) .

2. Environmental Applications:

in air Lead pollution has become a worldwide issue. Yang et al. investigated lead absorption from the environment using electrically charged plants that had been exposed to two lead-polluted plants. The findings found that silica exposed to polluted plants absorbed more ambient lead than SNPs that were not. Furthermore, this was the first study of its kind at the time (Azimi, 2017) (Yang, 2013).

3. Applications of in Food Preservation:

SNPs have been linked to food preservation as well as a variety of other uses. As a result, by coating them with silica-based hybrid films, many fruits may be stored for extended periods of time. This novel approach has been explored and validated by a number of researchers. Mirzadeh et al. created a hybrid nano-silica and chitosan composite film, for example. When the film was applied to the longan fruits, their shelf life was significantly increased. The film also decreased the tendency of the fruits to lose weight and become brown. Another study (Manzano, 2019) employed the same hybrid film coating on Loquat and discovered longer shelf life, greater enzymatic activity, and higher amounts of reducing sugars (Song, 2016) (Mirzadeh, 2007).

4. Chemical Applications of SNPs:

Specific locations on silica nanoparticles make it simple for the particles to become functionalized. For instance, the interior and exterior of the particle surface, as well as the pore walls and pore entry, are three important locations for functionalization in mesoporous silica nanoparticles (MSNs) (Song, 2016) (Mirzadeh, 2007).

5. Biomedical & Biotechnological Applications of SNPs:

Drug distribution is one of the most important areas of study in biomedicine. A critical component under investigation is the use of tailored nanostructures for the targeted delivery of medications to patients. These nanostructures have the potential to behave as transporters, conveying certain biological organs or tissues, MSNs have gotten a lot of interest in this sector because of their large surface area and porous nature. Recently, these particles have been used as nano-drug delivery systems (Song, 2016).

Properties of rice husk ash:

Depending on the temperature, three types of RHA are made when RH is locked up: amorphous, partially crystalline, and crystalline The RHA that comes from burning quickly in the open air has much carbon (C-RHA) RHA that is produced by burning at temperatures over 600°C has crystallized (Cr-RHA), but RHA that is produced by burning.

Typically, RH is burned at temperatures between 400 and 1000 °C for 2 to 5 hours. Amorphous silica-rich ash is produced when RH is burned at temperatures below 800 °C If the temperature increases, intolerable amounts of undesired crystalline silica will be produced. The combustion process is finished more rapidly as the temperature rises over 850 °C the silica in the ash produces agglomeration and then a shift to crystalline silica (Pode, 2016).

extracted at different incineration temperatures. RHA300 (incinerated at 300 degrees Celsius) demonstrates the porous structure of the adsorbent surface and a "corn cob" structure. RHA500 SEM constructions Due to the loss of less dense components, heating reveals the reticulated backbones and broken and elongated cell walls surrounding pores. RHA700's internal structure was less fractured and its cell walls were thicker than RHA500, resulting in fewer pores. Heating at 900o C (RHA900) creates tiny pores and internal ribs that seem interconnected .The XRD patterns of typical RHAs. Pyrolysis changed the crystalline structure of the cellulose into an amorphous, random, disordered structure that could attract things The large, smooth hump demonstrates this between 15o and 35o in the diffract gram a feature of amorphous materials, At 22 degrees Celsius, the peak intensity is between 500 and 700 ° Centigrade (2h). When heated to 900 degrees Celsius, peaks at 22 degrees intensified, and peaks at 43 degrees, 45 degrees, 47 degrees, and 49 degrees were also observed. As a result of this change to the crystal structure, there would be less surface available, making it harder to absorb things (Pode, 2016).

Sarangi, Bhattacharyya, and Behera, 2014 published a graph showing the fluctuation of the crystallite size of the calcined materials as an of nano silica derived from rice husk. The first regime, at temperatures between 500 and 700 C is a scenario in which the crystallite size increases gradually with temperature The second occurs at temperatures over 700 C when temperatures are more significant than 700 C aggregation effects become pretty severe, and the crystallite size significantly increases The aggregation processes caused by condensing the silanol groups (SiAOH) become essential It has also been shown that crystallite size rises mainly due to agglomeration when temperature increases from 700 to 1100 C, from 4.87 to 18.61 nm (Sarangi, 2009).

Conclusion:

In the field of nanotechnology, silica nanoparticles have already made a significant contribution. Mesoporous structure, large surface area, variable particle size, pore size and shape, and biocompatibility, among other exceptional qualities, provide significant benefits in a variety of applications.

In fields including agriculture, food preservation, biomedicine, and catalytic reactions, these nanoparticles have made notable contributions. It has been demonstrated that SNPs are good encapsulating agents for a wide range of bioactive compounds, which is already safe for the delivery of targeted drugs. Furthermore, the ability of SNPs to combine with other polymeric and non-polymeric materials to create hybrid composites has increased the range of functions that may be used.

Conflict of interest: None

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