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Novel Utilization and Applications of Rice Husk as Green and Sustainable Biomass

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Abstract: *Research on agricultural wastes management is state of the art and desirable subject in engineering subcategories. Recent developments in the reuse of agricultural residues/resources have led to environmental sustainability and cleaner technology emphasizing the utilization of natural resources. As a staple food for much of the world, rice production is widespread and its annual production generates huge quantities of husk (~1.5×10^{11} kg). Rice husk is easily collected and cheap, so it has always had some use as an energy source for small applications, and in recent years a number of rice husk derived products have been developed and is considered as one of the abundant and valuable agro-based residues. It contains a combination of cellulose, hemicellulose, and lignin, along with appreciable amounts of silica and inorganic components (ash). Rice husk pellets represent an alternative to diesel oil and coal for small scale electrical power generation. It is one of the abundant lignocellulosic biomass with potential as a feedstock for bioethanol production. Because of its high specific surface area, it has proven to be a potential low-cost material in the applications of water treatment and building materials. There are several reviews which demonstrate the ability of rice husks to remove various pollutants from water, including dyes, phenols, organic compounds, pesticides, inorganic anions, and heavy metals. Biogas can be generated by anaerobic microbial degradation of a combination of treated rice straw and animal waste. Fluidized bed fast pyrolysis with catalytic treatment of rice husk can economically produce primary pyrolysis oil that is suitable as boiler fuel oil and for the production of catalytically treated, upgraded, liquid-products. This economically valuable agriculture waste product is a great source of silica and has many comprehensive applications. Therefore the main objective of this review paper is to discuss the current research works focussing on the characteristics and suitability of Rice husk over a wide field of applications.*

Key Words: *Rice Husk, Biogas, Bio ethanol, Boiler fuel oil, Water treatment.*

1. INTRODUCTION:

Waste materials are either usable or unusable products left behind after production or formulation of the main products produced by the human activities. According to the Press Information Bureau, India generates 62 million tonnes of waste (mixed waste containing both recyclable and non-recyclable waste) every year, with an average annual growth rate of 4% (1). The agriculture sector is also contributing a large part through on field or off field activities. Few of the biggest global problems faced by mankind today are accumulation of waste and depletion of resources (2). One of the major contributors of waste is agricultural waste (Figure 1). In many parts in developing countries, agricultural solid wastes are indiscriminately dumped or burnt in public places, thereby resulting in the generation of air pollution, soil contamination, a harmful gas, smoke and dust and the residue may be channelled into a water source thereby polluting the water and aquatic environment (3).

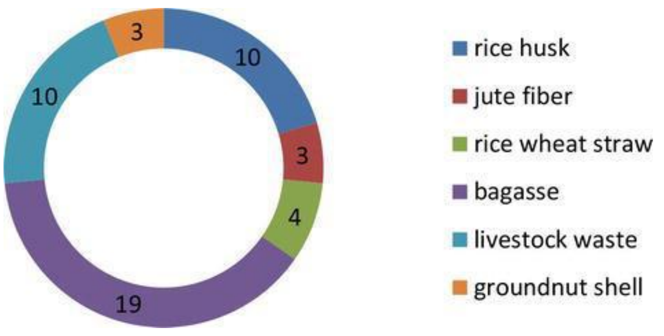

Figure 1: Agriculture waste percentage from different sources (4)

Research on agricultural wastes management, as a natural resource material, is state of the art and desirable subject in many engineering subcategories. The benefits include ease of access and implementation, affordability and environmental friendliness. Optimal use of agricultural wastes has always been a concern for humans, and the utilization of them for various purposes is an efficient way of environmental management (5). Considering the rising demand and necessity for sustainable and cradle to cradle ideology, the usage of wastes from a process as primary raw materials for another is a quintessential ingredient for the purpose. Recent developments have shown several alternatives in broader field areas as low-cost materials in replacement with the conventional materials used. A few among those industries are the construction field, cement manufacturing, paint industry, ceramics, adhesives, water stabilizers, nanofibers, dietary fibres, alcohol production, water purification, energy production, composting and landfill under controlled conditions (6).

One of the abundant, regular, and organic wastes, traditionally used in India since ancient times as an effective insulator, is Rice husk (RH) because of its low calorific and high thermal conductivity values. RH is the outermost protective layer over a rice grain. More than 50% of the world's population has rice grains (Oryza sativa) as their staple food. The RH generated from the milling industry form about 22% by weight of paddy and is used as an alternate fuel for paddy processing and producing energy through gasification (7). India being the second-largest rice producer in the world produces about 20 million tonnes of rice husk ash (RHA) (8). The major rice producers across the globe are indicated in Table 1. The untreated RH comprises of 75% organic matter of that 25% of ash is generated.

Table 1: Countries with major rice production (9)

Country	Rice Production (in million tons)
China	205.21
India	104.80
Indonesia	71.29
Bangladesh	51.50
Vietnam	44.04

RH is usually treated as a waste, and is burnt or dumped for its disposal. So far, RH has been used as a fuel and in paper industries. Though the idea of using RH as a primary raw material is gaining attention, a higher exposure and practicality is vital in making this a mainstream process. India alone has produced around 31 million tons of rice husk and thus generated 4.65–5.58 million tons (15-18% of RH) of RHA in 2014 proves the ease of its availability, which depicts the ideality as a raw material. RH contains 75-90% organic matter (cellulose, lignin, etc) and rest mineral components (silica, alkali) & trace elements. A typical analysis of RH is shown in Table 2. The content of each constituent depends on rice variety, soil chemistry, climatic conditions and even the geographical location. As a biomass product, rice husk combustion has neutrality of carbon emissions, in which carbon emissions are generated in a balanced combustion process with carbon reabsorbed in the next planting period. Hence, it not only leads to environmental and economic sustainability but also long-term sustainable socio-political stability.

Table 2: Typical Analysis of Rice husk (10)

Property	Range
Bulk density (Kg/m3)	96-160
Hardness (Mohr's scale)	5-6
Ash %	22-29
Carbon %	~35
Hydrogen %	4-5
Oxygen %	31-37
Nitogen %	0.23-0.32
Sulphur %	0.04-0.08
Moisture %	8-9

Rice husk is an essential in plastics, biofuels, charcoal, silica derivatives, carbon allotropes and pulp and paper technology (Figure 2). Because of its high carbon content, it is a great organic matter source. RH because of its high cellulose and lignin contents make it an ideal source of activated charcoal production (11). By the means of carbonization, the water vapour is evaporated and cellulose, hemicellulose and lignin are broken down and leave carbon to form Bio-briquette (12). Particle boards, which are used as a potential substitute for wood and wood-based products like plywood, insulation boards, ceiling boards as RH is unusually high in ash, which is 92 to 95% silica, highly porous and lightweight, with a very high external surface area. Its absorbent and insulating properties are useful in many industrial applications, such as acting as a strengthening agent in building materials. This also forms a base of production of card board from RH. One of the natural properties of RH, which is a boon to industries, is its high carbon content. This characteristic helps in generation of derived silica. This derived silica is proven to be a good filler in cement, fertilizers, catalyst and polymer matrices. The polymer compounds like natural rubber and polyolefins are obtained from this derived silica. Using fillers like this is economical and sustainable as raw material is waste from another process. RH subjected to carbonization produces RHA. Evidence suggests treatment of RHA with locally sourced raw materials produces Portland cement of commercial grade (5). RH currently is used majorly for production of ethanol, and solid fuels (13). A vast number of researchers have contributed to the field, and in recent years the study on RH as an important raw material is gaining attention.

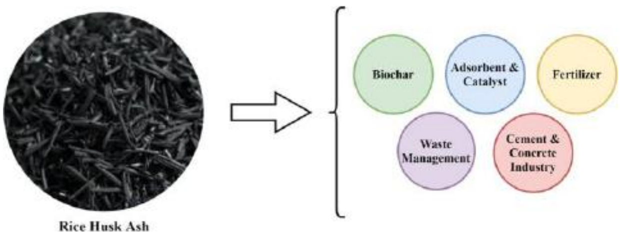

Figure 2: Overview of Rice husk applications (14)

Although Rice husk has been used throughout history, in many cases it has been used only on the basis of experience and not on the basis of science. However, with the advent of technology, scientists have realized that many factors affect the quality and characteristics of wastes (15). This review discusses the important properties and current research works focussing on the suitability of Rice husk over a wide field of applications. The treatment methodology of RH as an alternate source is elaborated with their respective advantages and disadvantages. Finally, the paper explores the challenges and opportunities of rice husk as green and sustainable material.

2. CHEMICAL COMPOSITION AND PHYSICAL PROPERTIES OF RICE HUSK :

RH is the hard shell covering paddy rice seed, which provides nutrients and metabolite accumulations during grain development, and protects seeds from physical damage. The structured layers of RH are divided into four categories, namely (1) the rough outer epidermis with surface hairs, where the silica is highly concentrated; (2) sclerenchyma; (3) spongy parenchyma cells; and (4) inner epidermis, whose surface is relatively smooth and free of hair (16). A study using back-scattered electrons and X-ray images of the RH showed silica was distributed mostly in the husk's outer surface whereas the midregion and inner epidermis contained less silica (17). RH is unusually high in ash compared to other biomass fuels in the range 10-20%. The ash is 87-97% silica, highly porous and light weight, with a very high external surface area (18). Presence of high amount of silica makes it a valuable material for use in industrial application. Other constituents of RHA, such as K_2O, Al_2O_3, CaO, MgO, Na_2O, Fe_2O_3 are available in less than 1 % (Table 3).

Table 3: Chemical composition of rice husk (9)

Constituents	Rice husk (by weight)
Silica	94.50
Oxide of Manganese (MnO)	1.09
Oxide of iron (Fe_2O_3)	0.54
Oxide of calcium (CaO)	0.48
Oxide of Magnesium (MgO)	0.23
Alumina (Al_2O_3)	0.21

Various factors which influence ash properties are incinerating conditions (temperature and duration), rate of heating, burning technique, crop variety and fertilizer used (19). The silica in the ash undergoes structural transformations depending on the conditions of combustion such as time and temperature. Typical dimensions of RH are about 8–10mm in length, 2–3mm in width, and 0.2mm in thickness (20). RH contains about 80% organic substance and 20% inorganic materials. Crude protein and fat are very low, ranging from 2.0% to 2.8%, and 0.3% to 0.8%, respectively, whereas crude fiber ranges from 34.5% to 45.9%, mainly including cellulose from 28.6% to 41.5% (Figure 3), hemicellulose from 14.0% to 28.6%, and lignin from 20.4% to 33.7% (21). The existence of silicon dioxide in high contents provides enough mechanical strength for it to function as an effective protective cover. This strength is enhanced due to the presence of this silica, as nanoparticles create surface layers. The successive layers are interconnected with cellulose fibers. This provides the RH, a tremendous mechanical stability.

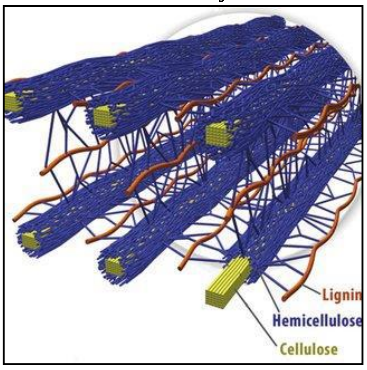

Figure 3: Spatial arrangement of cellulose hemicellulose and lignin in the cell walls of lignocellulosic biomass (22)

3. POTENTIAL APPLICATIONS OF RICE HUSK :

Recycling of crop residue is gaining back its intensification leading to the production of low-cost organic fertilizer. The production of biochar improves the soil fertility and increased nutrient contents of the soil, yielding effective plant growth. The presence of silica content enhances the bio-productivity in the biochar amended soil, thereby improving the silica mobilization to the plant growth (Figure 4). Studies analysed on fertility management of soil, have shown influences of RH amended soil in pH, soil electrical conductance (EC), ion exchange, organic content and some macro element such as potassium and nitrogen (23). RH has been identified as most economically important replacements in constructional industries. 85-90% amorphous silica is obtained by the controlled burning of rice husk under an optimum derived temperature of 650°C to 850°C. The replacement of conventional aggregates with rice husk ash is used as a good binding ingredient in the cement industry and other construction industry (24). The RHA exist in two main forms such as crystalline and amorphous, which has wide application in various industrial fields. Amorphous silica is useful in construction and rubber industries (25). RHA in cement or concrete leads to the improvement in various properties due to its fibrous, crystalline and amorphous nature. Researchers have proved that a replacement of 70% of pozzolanic material by RHA yields higher durability and strength than conventional cement mortar. In India, researchers are also focusing on the suitability of RHA in replacing SFs (26). The replacement of nanoparticles in the super-hydrophobic coating is replaced with the RHA, which enhances the roughness by the hydrophobic coating on the concrete.

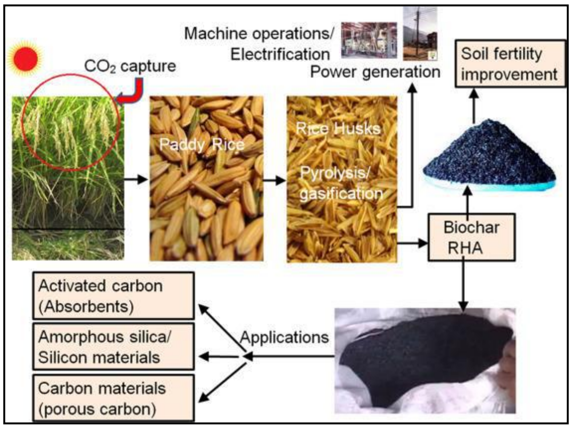

Figure 4: Potential applications of Rice husk (27)

The burning of biomass such into fuel leads to a renewable energy source with high calorific value, thereby satisfying the energy consumption needs and demands (Table 4). It is confirmed that the energy recovery from RH has a low release of CO_2 gas into the environment thus having a lesser impact than fossil fuels (28). Several biosorbents such as rice husk, corn, hemp, wheat straw and sawdust have been investigated for adsorbing the dyes and heavy metals present in water and wastewater. The adsorption capacity of 16.9 mg/g was observed on RH adsorbent in removing synthetic silk yarn. Arsenic (As), one of the major groundwater contaminant had effective removal by column adsorption studies using RH adsorbent. A number of pure and complex form of silicon compounds like zeolite, silicon carbide, silicon chloride and nitride are extracted from 15% - 20% silica present in the RHA (29). These extracted compounds are used in the purification of impurities with fine dispersion. The use of RH based compost processed through aerobic degradation increases the nutrient value of the unprocessed soil. The end products thus obtained can be used as a rich soil conditioner. Attempts have been made to utilize RH to synthesize High-Performance Phosphors and RHA in vulcanizing rubber. RHA is used during the production of high quality flat steel. The ash also finds application as an excellent insulator, having fine insulating properties including low thermal conductivity.

Table 4: Calorific value of major agricultural residues (9)

Agricultural residue	Heating or calorific value (MJ/kg)
Sugarcane bagasse	17,700
Corn stalks	16,800
Hemp	16,500
Rice husk	16,000
Wheat straw	15,000
Rice straw	13,500

4. SUSTAINABLE MANAGEMENT OF RICE HUSK :

(i). Cement Production:
The term cement is a name given to powdered minerals which when mixed with water form a plastic body that can easily be shaped and that hardens gradually to yield a strong stone-like structure. Silica is a major component in Portland cement. The principal constituents of Portland Cement are Tricalcium Silicate and Dicalcium Silicate. It is observed that the price of cement is growing everyday, so using inexpensive materials is important. Due to the high silica content in the RHA it can be used as a good source of derived silica. Using rice husk ash for silica is found to be economical and is on par with quality of commercial cement produced from the normal processes. White ash is produced by burning RH in two steps (Figure 5). Rice husk is pre-carbonized and is subjected to treatment. Later on it is decarbonized to give White Ash. This method is known to be more efficient as it involves burning rice husk, which is known to be easily burnt with a fuel. The cost for combustion is drastically reduced as electricity is not required to carry out the process.

With the use of a stove and fuel like kerosene, RH is lit and it continues to burn. Burning of Rice husk is known to be a source of carbon dioxide, and the emissions are on par with the conventional methods using furnaces. But the inclusion of RH makes the process economical as it uses inexpensive waste materials. It also is known to reduce the weight of produced concrete (30). In addition, RH used along the conventional fly ash in the deep mixing of cement provides similar benefits such as improving strength, reducing costs and using agriculture generated waste. The efficiency of rice husk ash depends on the proportion of the cement, rice husk ash, and water content in the mixtures as well as the curing time. The RHA enhances the strength of cement-admixed clay by larger than 100%, depending on the addition rate and mixing components. For the curing period of 14 and 28 days and the range of water content in this study, the rice husk ash exhibits higher efficiency on Portland cement replacement when the cement and cementitious contents in the mixture are not less than 20 and 35%, respectively. The RHA content in overall cementitious materials which enhances the strength of the mixture can be larger than 50%. When compared with fly ash of similar grain size, the efficiency of rice husk ash is higher when the content to be added is greater than 15%.

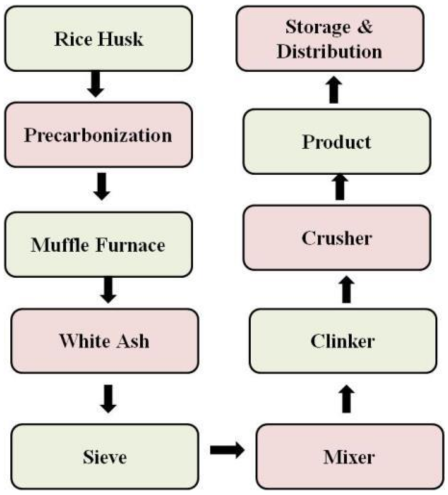

Figure 5: Flow diagram for the production of white Portland cement from rice husk ash

(ii). Particle board Production:
Lightweight and high-strength wood and wood-based composite boards are the preferred option for construction due to their reasonable costs. The growing shortage of wood has also led to the development of suitable alternative materials for construction. Rice husk particleboard is one such material, which is being considered as a potential substitute for wood and wood-based board products. The use of natural sponge particles (rice husks) as reinforcement for the production of particleboard was the thrust recent research works. These fibres being cheap and readily available with low energy demand during manufacturing have been strong contender for research. The reasons behind the use of RH in the construction industry are its high availability, low bulk density (90-150 kg/m^3), toughness, abrasive in nature, resistance to weathering and unique composition. The main components in RH are silica, cellulose and lignin (31). The first step in preparation of particleboards from rice husk is grinding the rice husk in to particle size (Figure 6). Fine particles of rice husk are obtained by ball milling. Then, the obtained fine particles are screened using sieving machine using the fine sieve to attain uniform size and to avoid swelling of rice husk. 20g of RH (20%) is added slowly with constant stirring to in to the container containing Polyester resin of about 200 ml. Then about 1.5 ml of accelerator is added to the mixture and is stirred well until uniform mixture is attained. The catalyst (which has no reaction chemically with the mixture, but speeds up the reaction) of about 1.5 ml is added to the mixture and is stirred well. The mixture itself will settle without the addition of catalyst but takes very long time to get harden. So catalyst is added to speed up the reaction, which reduces the time taken for making the board. Once the catalyst is added and the mixture is stirred well, it is poured in to the mould (die with spacer) measuring 250mm x 250mm x5mm. The mixture is allowed to flow on its own inside the mould. Then a slight pressure is applied on mould my manual pressing (or) by placing weights above the mould. The mixture inside the mould is allowed to settle down in the mould. The settling time for the mixture inside the mould is around 10 hours. After 10 hours of settling time the mould is carefully removed and the board is obtained. The rice boards can be used as an substitute for false ceiling boards. Due to the non-conducting nature of the rice husk boards it can be used in electrical circuits. It can be used in manufacture of switch boards, circuit boards, switches etc. They can also be used in making partitions in shelves, cabinets as a substitute for wood and concrete which is costlier as compares to rice husk boards (32). Because of the high silica content the boards turn termite resistant, and

are known to be lightweight in comparison with the conventional market grade. The boards through this process are proven to be water resistant to an extent. These results make Rice Husk a futuristic raw material in the particle board industry.

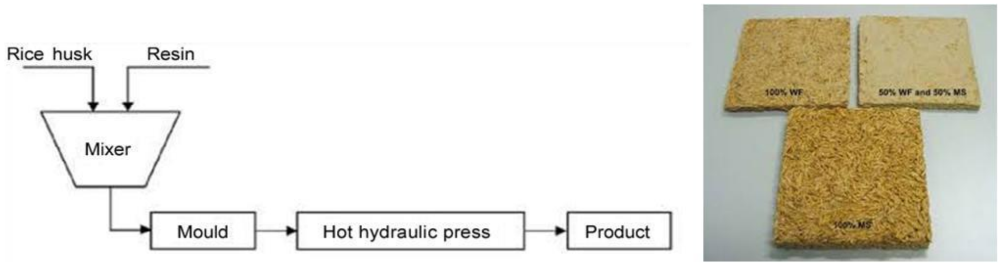

Figure 6: Procedure for manufacturing of particleboards from rice husk

(iii). Biogas Production:

Biogas has been known to be a great environmental benefitting method to make biofuel, by using waste. Along with organic waste, Rice husk is proven to be an excellent source to produce biofuels due to the presence of essentials of biofuel production like cellulose, hemicellulose, lignin and other inorganic materials. Biogas is obtained from Rice husk majorly by the process of fermentation. This has been in use since a decade, and is an important procedure in producing biogas from agricultural waste. However, recent studies show that pre-treatment of RH fetches better yields. Important steps in the pre-treatment process are:

1. Chemical Treatment
2. Biological Treatment
3. Physical Treatment

The main content of rice husk is cellulose (59%), hemi-cellulose (19%), lignin (20%) and ash (1%) (33). The high content of cellulose, making rice husk is excellent potential for anaerobic digestion. However, it has high lignin which will disturb the decomposition by micro-organism. Therefore, the pre-treatment is required to remove the lignin content from the rice husk. In chemical pre-treatment, Prior to biogas production, the rice husk was pre-treated by using NaOH 3% in order to remove the lignin. After pre-treatment, enzyme, C/N ratio and total solid content were adjusted according to central composite design at the variation of 3-6% enzyme concentration, C/N ratio of 20-50 and total solid of 15-40%. The substrate is mixed with inoculum and water according to the TS concentration as well as the technical urea to adjust the C/N ratio variation and the enzyme is added accordingly. The prepared substrate is fed into the bioreactor, sealed tightly for anaerobic conditions and ready for operation. The biogas volume is monitored by passing the gas into a water-filled measuring cup every 2 days (34).

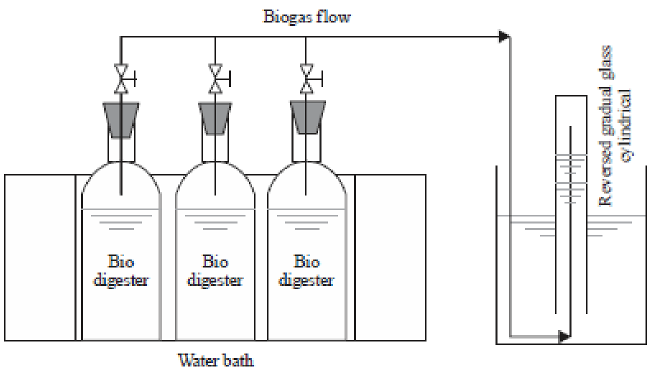

Figure 7: Schematic diagram of biogas measurement

In biological treatment, microorganisms are used for lignocellulosic pre-treatment and increases enzymatic hydrolysis. Microorganisms are usually applied to degrade lignin and hemicellulose but very few parts of cellulose, because cellulose is more resistant than other parts of lignocellulose with biological treatment. The digestion takes place either at a temperature of 30-40°C for mesophilic conditions and at a temperature of 45-60°C for thermophilic conditions. Generally solid state anaerobic digestion (SS-AD) can be operated under mesophilic conditions. The pH range of 6.8-8.0 is an optimal condition favoured by most microorganisms for anaerobic digestion. The activity of microorganisms that play a role during the fermentation process depends on the C/N ratio. In anaerobic digestion the optimal C/N ratio is about 20-30 (35). The total solid content affects the pH value and the effectiveness of microorganisms in the digestion process. The total solid concentration in the SS-AD system is about 20-30%. The substrate (feedstock) is converted to methane by anaerobic bacteria. Bacterial growth in the anaerobic digestion process can be accomplished by the addition of an inoculum or nutrient. This is because microorganisms need energy source to move on biogas production process. Nutrients required are macronutrients such as carbon, nitrogen, hydrogen, phosphorus, potassium and sulphur as well as micronutrients such as iron, copper, nickel, molybdenum, tungsten, cobalt and zinc. The ratio of F/I used in the SS-AD system ranges from 2-6 (36). Physical pre-treatment can increase surface area, reduce crystallinity and degree of cellulose polymerization. This is done by various processes like milling, grinding, ball milling etc. Smaller substrate pieces can open cellular structures and increase the specific surface area of biomass. It also increases the rate of enzymatic degradation, which is very important for lignocellulosic substrates (37). In addition, it can reduce the viscosity in the digester (thus making mixing easier) and can reduce the problem of floating layers. The highest biogas yield was found in 60 mesh reactor, which produced a biogas yield of 143.5 ml. The smaller the size of the substrate, the more gas volume results. Because the digestion process of microorganisms decomposes becomes faster.

(iv). Adsorbents for water purification:

Some of the adsorbents prepared from RH are silica, zeolite, activated carbon, biochar, metal silicate, and hydrogels. Silica is a major component of the residual part of RH, and thus several chemical treatments are explored for extraction of silica and its derivatives from RH. Activated carbon (AC) is an important adsorbent derived from RH. It has high porosity, high surface area, low bulk density, and is non-hazardous. The basic reaction for preparation of AC is carbonization, which is based on the pyrolysis of RH under different conditions prepared AC by carbonizing RH at 400 °C under a nitrogen flow of 300 mL min−1 for 90 min (38). The obtained product was impregnated with NaOH in weight ratio of 1/3 followed by thermal treatment. The activated AC shows high surface area and suitability for industrial applications. In modified carbonization processes, the RH has been converted into carbon nanotube (CNT) and graphene. These are the allotropes of carbon with two dimensional structures along with unique physical, mechanical, electrical, and surface properties.

(v). Rice husk Biochar

Biochar can be defined as any biological residue from any organic based materials produced through gasification or pyrolysis at 300-600°C under exclusion of oxygen. Rice husk biochar (RHB) account for 20% of rice weight and it contains 50% cellulose, 25–30% lignin, 15–20% silica and 10–15% moisture. Converting rice husk into rice straw into RHB and recycling it back to the paddy field as a soil amendment can be an effective solution in rice waste management. The biochar yield form rice husk is approximately 35% of its feedstock material. RHB contains SiO_2, Al_2O_3 and Fe_2O_3. Availability of moisture in the soil is always a vital component in ensuring good crop growth. Adding 4 t/ha RHB to the soil increases the soil water holding capacity and nutrient retention in the soil through improved cation exchange capacity level. Also, adding RHB at the rate of 40 and 80 Mg ha^{-1} was sufficient to improve soil physical properties where soil bulk density was significantly lower while total porosity, macro porosity and available water capacity increased (39).

5. CHALLENGES AND OPPURTUNITIES OF RICE HUSK :

The combustion of Rice Husk tends to liberate CO_2. Although these emissions are observed to be close to the conventional industrial processes, the other greener aspects of rice husk outweigh its bottlenecks. These properties of Rice Husk such as the Carbon content, and other essential properties are influenced by the geographical location and conditions it was harvested. These varying properties might sometimes pose a problem to generalise the optimum conditions. Another minor problem faced during the initial stages of Rice Husk usage is due to its porous structure, which increases the difficulty of transportation. These could be cleared easily through general measures. The unburnt rice husk deteriorates the overall performance quality of cement. This RHA could be a threat to the surroundings if it is just dumped. So a complete utilisation is ideal, nevertheless, a lot of ways can be implemented for disposing or making commercial use of this. The high silica content of Rice Husk might contribute to the rapid wearing of parts of the equipment such as grinders, conveyors. Another concern is the fouling, and agglomeration in the boilers and combustors due to high ash, alkali and potassium content. However, these challenges could be tackled easily by usage of proper amounts of products, maintaining optimum conditions and using well lined (glass lined) equipment. Rice husk has been used directly or in the form of ash as a value added material for synthesizing new materials or as a low cost substitute material for modifying the properties of existing products. Presence of silica is an additional advantage which makes

RH an important material for a wide range of manufacturing and application oriented processes. Easy availability and low price is an extra benefit towards the use of this material. Despite having high potential and suitability in so many well established uses, its use has been limited. In the competitive market, proper utilization of rice husk and its ash will benefit industrial sectors. The use of rice husk as fuel/electricity generation in efficient manner is likely to transform this agricultural waste material in to a valuable fuel for industrial sectors. A systematic approach to this material can give birth to a new industrial sector of rice husk.

6. CONCLUSIONS :

The use of agricultural wastes as a sustainable and renewable energy resource has huge potential as low-cost precursors for the production of valuable materials. The benefit of this waste is sustainability and environmentally friendly. It is concluded that using rice husk ash for silicon materials production are a sustainable option. This rationale review provides a comprehensive study of properties of Rice Husk and its usage as primary raw material to counter the low reutilization scenarios prevailing. This article also provides a qualitative and consolidated list of few obtainable products from Rice husk like cement, bricks, boards, biofuels etc to promote the usage of waste and sustainable engineering. The study also shows a comparative analysis of the manufacturing process of the above mentioned products, and modern and better approach to their synthesis. With these as a base, we believe to create a handbook for researchers' looking for a brief study of Rice husk utilization. The environmental impact assessment shows that the life cycle of a RH will have lesser negative impacts. Being one of the main sources of biomass, RH is used as an energy source in many different applications and has been successful in reducing the consumption of fossil fuels. Therefore, the future of RH depends on the efforts towards fulfilling price as well as performance requirement. It is anticipated that the ongoing marketing activities in several countries will soon make RH available for multiple applications in different areas.

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