



Novel Approaches Towards Sustainable Management of an Agricultural Residue - The Rice Husk

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ABSTRACT

Recent developments in the reuse of agricultural residues/resources have led to environmental sustainability and cleaner technology emphasizing the utilisation of natural resources. Novel approaches to sustainable and energy conservations inter-relates the scientific and practical applications employed in engineering solutions. The increasing importance of biomass had led to an acute need for mitigating global sustainable problems. In the third world economics, Rice Husk (RH) collected from rice milling industry is considered as one of the abundant and invaluable agro-based residues. A focus on industrial food production and its sustainability is due to the generation of huge quantity of RH. The improper handling and disposal management of RH has resulted in environmental and population health risk, due to its large space occupancy and leaching. The effective utilization and study of rice husk in various industrial applications such as construction industry, energy production, water purification and soil stabilization have shown acceptable results. This review discusses the current research works focussing on the suitability of RH and its ash over a wide field of applications. Silica being the dominant content in RH and Rice Husk Ash (RHA) has attracted interest among the researchers to develop it into high strength composite materials, porous nanomaterials, a precursor of renewable energy and soil stabilising biochars. Replacement of fine aggregates with RHA has improved the strength and durability of the concrete. The RHA is also developed into an adsorbent and coagulant in water purification. The binding between the ions present in impure water and highly reactive silica bond enhances the removal efficiencies of metal ions in water treatments. Very few researches are carried out using RH compared with the pyrolyzed RHA as an alternative. This paper highlights the various field of RH applications and suggests composting of RH with nitrogen-rich garden waste to obtain an enriched soil stabilizing product with high nutrient and organic value. This approach would restore RH in its the place of generation, thereby improving the economic value of the agricultural mass and sustainable way of living.

INTRODUCTION

The major sustainability challenge faced by the earth is environmental degradation caused by the deterioration of the biotic and abiotic resources. The huge quantity of waste generated from natural resources such as plants and biomass has led to a serious disposal problem along with the release of synthetic/man-made pollutants. The conventional practice in disposing of these wastes are either to burn or naturally convert into organic fertilizer under favourable conditions. The decomposition of organic matter leads to water pollution by releasing dreadful pathogens causing various diseases in the surrounding environment. 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, nanofibres, dietary fibres,

alcohol production, water purification, energy production, composting and landfill under controlled conditions.

One among the agricultural wastes is the Rice Husk (RH). This review paper discusses the wider applications of RH in various fields. Inefficient use of agricultural wastes on vegetative lands for soil amendment is limited. Studies have shown the negative nutrient balance leading to a decline in soil fertility in traditional farming (Tewodros et al. 2007). Replacement of nutrient and feed with organic amendments in an effective manner are viable options for soil fertility and crop production (Negassa et al. 2015, Dercon & Christiaensen 2011). The treatment methodology of RH as an alternate source is elaborated with their respective advantages and disadvantages. A suggestion is also given in using RH as a soil stabilizing agent by composting. The significance and utilization of compost derived from RH in increasing the soil organic content are also discussed.

Rice Husk (RH)

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 (Patil & Sharanagouda 2017). India being the second-largest rice producer in the world produces about 20 million tonnes of RHA (Shwetha et al. 2014). 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. The chemical composition and analysis of RH is given in Table 2. The alternate usage of RH and RHA in a wide field of applications such as synthesis of highly porous carbon fibres, development as catalyst and chips and lightweight construction materials are briefly summarized in this review.

ALTERNATE USE OF RICE HUSK (RH)

Biochar Production

Recycling of crop residue is gaining back its intensification, due to awareness among the rural agricultural mass 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. The silica beneficiates the plant by reducing metal toxicity, salt content and supports in increasing culm wall thickness and vascular bundle. Addition of biochar in agricultural land shows lower bulk density and improved water holding capacity by 77.92% (Lehmann et al. 2009). Studies analysed by Ghorbani & Amirahmadi (2018) 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.

Construction Industry

Agricultural biomass and residues such as husk and hulls of

Table 1: Countries with major rice production.

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

rice and groundnut, fibres of coir, kenaf and jute, straw and sawdust have been identified as most economically important replacements in constructional industries. The rice husk under the focus of study cannot be used as an alternative replacement material and is used only as RHA. 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 (Nehdi et al. 2003).

The major factor influencing the grade of RHA is the burning condition of rice husk including the burning temperature. The RHA exist in two main forms such as crystalline and amorphous, which has a wide application in various industrial fields.

Unlike steel and ceramics industries using crystalline silica, amorphous silica is useful in construction and rubber industries (Mehta & Pitt 1976). Table 3 shows the preparation of RHA under various conditions with their strengths and workability. 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. Though many ongoing research works are carried over due to the amorphous nature of silica, an increase in compressive strength observed in many studies was due to

Table 2: Chemical composition, proximate and ultimate analysis of rice husk.

| Constituents | Rice Husk (by weight) |
|---|-----------------------|
| Silica (SiO ₂) | 94.50 |
| Oxide of manganese (MnO) | 1.09 |
| Oxide of iron (Fe ₂ O ₃) | 0.54 |
| Oxide of calcium (CaO) | 0.48 |
| Oxide of magnesium (MgO) | 0.23 |
| Alumina (Al ₂ O ₃) | 0.21 |
| Proximate Analysis | 15 |
| Fixed carbon (%) | |
| Volatile matter (%) | 67 |
| Ash (%) | 18 |
| Ultimate Analysis | 40 |
| Carbon (%) | |
| Hydrogen (%) | 5 |
| Nitrogen (%) | 34.8 |
| Oxygen (%) | 0.8 |
| Sulphur (%) | 0.1 |

(Reference: Ghosh & Bhattacharjee 2013)

Table 3: Characterization of RHA in the construction industry.

| S.No. | Constituents | Combustion time/ temperature | Analytical methods | 28 days Compressive strength (Mpa) | References |
|-------|---------------------------|---------------------------------|--------------------|---------------------------------------|---------------------------|
| 1 | 10% RHA | 400°C - 600°C | - | 22 | Godwin et al. (2013) |
| 2 | 20% RHA + 10% Microsilica | 6h/680°C | XRF | 93.28 | Zareei et al. (2017) |
| 3 | RHA | - | XRD, SEM | 35.39 | Kaur et al. (2018) |
| 4 | MgO + RHA | - | XRD FT-IR, OM, SEM | 1.1 | Qin et al. (2018) |
| 5 | 20% RHA | 1h-4h/550°C - 700°C | XRD, EDAX | 168.6 | Vigneshwari et al. (2018) |

the increasing percentage of carbon present in RHA. The fineness nature of the RHA enhances the pozzolanic reaction and is effectively carried out in Reactive Powdered Concrete (RPC) production. The Silica Fume (SF), one of the major constituent present in the RPC makes the reaction rate faster. In India, researchers are also focusing on the suitability of RHA in replacing SFs (Raman et al. 2011, Van et al. 2014, Van Tuan et al. 2011).

Super-hydrophobic coatings and admixtures for construction materials are widely used in recent year due to their anti-corrosion, anti-icing and anti-fouling nature (Junaidi et al. 2016, Ramachandran et al. 2016, Tittarelli & Moriconi 2011). 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.

Energy Production

For millennia, the conventional energy source on the planet is the biomass. The burning of biomass such as hulls, corn and jute into fuel leads to a renewable energy source with high calorific value, thereby satisfying the energy consumption needs and demands. The RH contains 30 -50% of organic carbon with a high calorific value of 13,000 to 16,000 KJ/kg, whereas the power plant ranges between 9,500 KJ/kg to 27,000 KJ/kg. Table 4 gives the heating value of some of the predominantly used agricultural residues. Though the organic content and ash content is higher than coal, the fixed carbon content of RH is much lower than in coal. The lower fixed carbon content in RH and the wearing of components during Rice Husk processing is a major limitation of RH energy conversion. 198 kg of RH is utilized to generate 1 MWH by boiler with the emission of gases such as CO₂, CO, NO₂, SO₂ and total suspended particles (TSP). Due to the limitations, the rice husk fuel power plant is operated and appended with water pre-treatment and electricity generator units (Prasara & Gheewala 2017).

The bio-oil yielded by direct or indirect combustion minimizes the formation of biochar. The stored bio-oil and the other liquid derivatives such as carboxylic acids and other biomolecule compounds can be used in food and chemical

industries. It is also confirmed that the energy recovery from RH has a low release of CO₂ gas into the environment thus having a lesser impact than fossil fuels (Swaina et al. 2011).

Water Purification

Adsorption: Several biosorbents such as rice husk, corn, hemp, wheat straw, coffee and tea waste, fruit peel, seed hull and sawdust have been investigated for adsorbing the dyes and heavy metals present in water and wastewater. During the last decade, extensive research was explored and carried out in this area for removing organic and inorganic compounds such as chloro-phenols, other pharmaceutical and pesticide pollutants (Chuah et al. 2005, Gupta et al. 2006, Lata & Samadder 2014).

The pre-treatment of amorphous silica in developing it into highly reactive activated carbon with improved specific surface area is an important technique in the preparation of RH carbon. The effect of chemical treatment increased the surface properties of RHA and was reported by Alyosef et al. (2013), Salas et al. (2009). However, some limitations and setbacks were identified in the pre-treatment process observed from previous literature. The results for the work carried by Chen et al. (2018) showed non-interference of adsorption process due to the presence of potassium (K), calcium (Ca), magnesium (Mg) and manganese (Mn). About

Table 4: Calorific value of major agricultural residue/resource.

| Agricultural residue | Heating or calorific value (MJ/kg) |
|----------------------|------------------------------------|
| Flax | 17,800 |
| Jute stick | 17,800 |
| Sugarcane bagasse | 17,700 |
| Corn stalks | 16,800 |
| Switchgrass | 16,800 |
| Hemp | 16,500 |
| Hay | 16,200 |
| Rice husk | 16,000 |
| Wheat straw | 15,000 |
| Rice straw | 13,500 |

Table 5: Organic composition of rice husk.

| Organic constituents | Composition in percentage |
|----------------------|---------------------------|
| Hemicellulose | 22.82 ± 1.50 |
| Cellulose | 33.32 ± 1.05 |
| Lignin | 20.32 ± 1.12 |
| Ash | 16.95 ± 1.90 |
| Trace elements | 3.25 |

70%-98% of these metal were further removed by leaching in suitable solvents such as water and acid. The adsorption capacity of 16.9 mg/g was observed on RH adsorbent in removing synthetic silk yarn. A positive value of H (160.97kJ/mol) showed endothermic adsorption (Sawasdee et al. 2017). Arsenic (As), one of the major groundwater contaminant had effective removal by column adsorption studies using RH adsorbent. Furthermore, intensive research in the development and applications of RH adsorbent is prevailing for the last three decades. Ahmaruzzaman & Vinod (2011) have reviewed the removal of pollutants on rice husk under favourable parametric conditions and their adsorption mechanisms.

Coagulant: 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 (Adylov et al. 2003, Matori et al. 2009). These extracted compounds are used in the purification of impurities with fine dispersion. These ligno-cellulosic derivative compounds contain active sites of tannins and lignin entrapping the heavy metal cations to form immobilized complexes or chelates through the ion exchange process. Table 5 represents the organic composition of RH.

Some of the agro and biomass wastes are by nature good in coagulation mechanism, which are derived from the various plant components such as seed, root, bark, leaves etc. These may be commercialized in future at a lower price for water purification technique. A cost-effective and environmentally friendly coagulant can be prepared and installed in a water purification system for removing suspended particles. Previous studies have shown effective removal efficiencies with proven results using plant-based coagulants.

A study was conducted to remove the turbid water using RHA derived from carbonization of RH. About 96% of turbidity was removed with high TDS (816 ppm) as observed by Adams et al. (2014) by using Rice hull ash as the coagulant. The coagulation mechanism and biological treatment process have shown higher removal of chemical oxygen demand (COD) of about 85% for various domestic and industrial effluents. Though effectiveness in the removal of organic matter was observed, excessive sludge generation, frequent pH variations, cost and skilled personnel were limiting these treatment techniques to be established at large scales (Mehta & Chavan 2009). Table 6 summarizes some of the recent treatment and process investigations in the removal of dyes, organic and inorganic constituents.

In India, a large part of the country has poor organic content in the soil. Sustainability and productivity are restored by appending the soil with the required and needed nutrients and conditioners. The efficiency of the plant growth and soil requirement is increased by the application of fertilizer produced from biomass and crop residues. The processed organic compost mixed soil strengthens the structure of the soil and void ratio, improves water holding

Table 6: Treatment methodology for water purification and removal efficiency.

| Type of dye/metal ion | Purification technique | Modification/ Pre-treatment | Pollutant Removal Efficiency (%) | Reference |
|-------------------------------|------------------------|---------------------------------|----------------------------------|----------------------------|
| Strom water –Suspended Solids | Coagulation | RHA | 93.34 | Nnaji et al. (2017) |
| Basic Green 4 | Adsorption | Con. Nitric acid pre-treatment | - | Guo et al. (2003) |
| Congo Red | Adsorption | Rice Husk | 84 | Han et al. (2008) |
| Phenols | Adsorption | ZnCl ₂ impregnation | 80 | Kalderis et al. (2008) |
| Acid Yellow 36 | Adsorption | Steam activation | 90 | Malik (2003) |
| Methylene Blue | Adsorption | Rice husk | - | McKay (1986) |
| Cr (VI) | Electro-coagulation | Rice Husk | 97 | Ait Ouaiassa et al. (2013) |
| Zn(II) | Adsorption | Grounded | 90 | Roy et.al. (1993) |
| Cr(VI) | Adsorption | Acid impregnation/Carbonization | 99 | Srinivasan et al. (1988) |
| Pb | Adsorption | Tartaric acid impregnated | 86 | Wong et al. (2003) |
| Cu(II) | Column Adsorption | ZnCl ₂ impregnation | - | Yahaya et al. (2011) |
| As(V) | Column Adsorption | Rice Husk | 90.7 | Asif & Chen (2015) |

Table 7: Rice husk composting and their physical and chemical properties.

| Compost material | Compost period (days) | Physical Properties | | Chemical Properties (%) | | | | | | Plant yield (%) | Experimental Design | References |
|-------------------------------------|-----------------------|---------------------|---------|-------------------------|------|------|------|-------|------|----------------------------|-----------------------------------|-----------------------------|
| | | pH | EC ds/m | OM % | N | P | K | C | C/N | | | |
| Rice Husk | 90 | 7.66 | 1.16 | 9 | 0.55 | | | 21.14 | 38:1 | 7.77 (ton/da) (tomato) | Randomized plot | Zeynep & Coskun (2015) |
| RH + Enhydrobacter+ Aspergillus sp. | 90 | 7.8 | 0.27 | 16 | 1.10 | 0.96 | 1.24 | 25.62 | 14:1 | 16 & 17 (black & red soil) | Pot Experiment | Thiyageshwari et al. (2017) |
| RH + Chicken bones | 60 | 8.03 | 0.30 | 39 | 1.64 | 1.26 | 1.02 | 43.24 | 30:1 | - | Complete Randomized plot & ANNOVA | Shareef et al. (2016) |
| RH | 219 | 7.02 | 0.33 | - | 2.90 | - | - | 53.0 | 13:1 | - | - | Leconte et al. (2009) |

capacity and microbial activity. The compost-rich soil has high nutrients and can be used in natural and organic farming. 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 in small and large scale agro-farming for further substantial yield and productivity.

COMPOSTING

The sustainability of soil could be reached by adopting improved agricultural management and practices such as leguminous and cover crop plantation. This leads to the reduced application of fertilizers and pesticides, thereby enhancing carbon sequestration to restore the environment by preventing global warming. The improvement in soil quality and soil parameters are influenced by the organic and nutrient level of the soil (Cercioglu et al. 2014, Gulser & Candemir 2012). The biochemical and geological properties show good improvements in the addition of organic compost along with the soil. The abundance availability of rice husk is a major problem in the agricultural sector leading to environmental degradation. A suitable and sustainable approach in improving the agricultural land, thereby improving the soil and crop productivity is suggested in this study. By Applying 9% RHCA, Zeynep & Coskun (2015) could reach a tomato yield of 7.77 tons/da. Also, the usage of garbage compost resulted in an increased yield of about 43% in comparison with the application of chemical fertilizers. Researchers have reported that the addition of organic compost has improved the electric conductance of the soil (Candemir & Gulser 2011). Table 7 summarizes the application of various compost residues for plant growth and their effects on the physicochemical properties.

CONCLUSION AND FUTURE SCOPE

In most of the research work carried so far, RHA is utilised as the raw materials as an alternative source in various fields such as building construction, energy production, water purification etc. A very few attempts have been made in the disposal of RH as a natural component. One such way is the composting of RH yielding a higher C/N ratio to enrich the soil fertility. Studies have shown the higher organic matter in the end compost forms a strong stabilizing agent. The major elemental constituent of RH are K, Ca, Zn, Fe and Mn. Though the ionic leaching of the RH in natural dumping is studied, no specific effect in the degradation of contamination of the ground soil and water is discussed. Based on the review of various research papers, further study of this work will focus on the composting of the RH with a nitrogen-rich waste such as garden waste. The soil leaching studies during the composting are also to be studied.

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