

# Biochar-treated rice mill effluent: a sustainable strategy for enhanced reusability

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**Abstract:** Rice mill wastewater contains a high concentration of organic and other pollutants put threat to agriculture if released without treatment. This research investigates the utilization of rice husk biochar as a sustainable material for treating and enhancing the quality for potential reuse of rice mill effluent. This work assesses efficacy of treatment on crucial factors, including decrease in lignin and phenolic compounds, decrease in physicochemical parameters, and a change on microbial composition. The application of biochar facilitated the adsorption-based pollutant removal, resulting in an overall enhancement of water quality. The treated water showed optimum pH with major reductions in turbidity (90.38%), TSS (74.02%), conductivity (66.21%), TDS (64.70%), and COD (26.18%), demonstrating that biochar-assisted treatment is an effective, eco-friendly method for rice mill wastewater reuse in irrigation and other non-consumptive applications, supporting sustainability.

## 1) Introduction

Rice milling process produces significant amount of effluent that contain high levels of organic pollutants, nutrients, and dissolved solids, including starch residues, chemical oxygen demand (COD), total dissolved solids (TDS), suspended solids, lignin, and phenolic substances. Discharging this effluent untreated can lead to major environmental issues, which makes effective treatment crucial prior to discharge or reuse [1].

Traditional treatment techniques for rice mill wastewater frequently demonstrate limited effectiveness in eliminating leftover organic and phenolic pollutants and can entail high operational expenses. This has resulted in a growing interest in using cost-effective treatment materials sourced from the rice industry.

Biochar made from rice husks serves as an eco-friendly adsorbent for treating effluents from rice mills, thanks to its porous structure and functional surface groups which facilitate the efficient elimination of

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organic pollutants [2]. As it is generated from byproducts of rice milling, it contributes to waste valorization and the principles of a circular bioeconomy, with prior research demonstrating its effectiveness in removing phenolic compounds and other contaminants from wastewater [3,4].

## 2) Objective

The objective of this work is to treat the rice meal effluent with rice husk biochar to assess the overall quality of rice mill effluent by analyzing its physicochemical and microbiological characteristics, and to evaluate the potential reusability in comparison to the standard.

## 3) Materials and Methods

Sample of rice mill effluent was obtained from a rice mill of Bardhaman District of West Bengal.

The rice husk biochar (prepared by using the husk from the same rice mill) was used as filtration bed in the form of saturated column through which the rice mill effluent was passed. The biochar was prepared by pyrolysis of rice husk at 350°C for 1 hour and resulted in porous surface properties. The filtered water was collected from the column collecting each drop in 15 seconds and the total run time was 1 hour to collect filtrate in a beaker. The full length of the filtration column was 23 cm with the biochar occupying 15 cm and the volume was 1024 cm<sup>3</sup>. The column was washed after every run and was changed after three runs.

This study was planned to understand the potential of this rice husk biochar to treat the effluent, hence, the key physical and

chemical parameters including pH, temperature, conductivity, and turbidity, along with the total solids (TS), total dissolved solids (TDS), lignin, phenol, sulphate, and phosphate were measured using standard analytical procedures. The organic pollution load of the effluent was estimated by Chemical Oxygen Demand (COD). The microbial composition of the wastewater was done to identify the presence of pathogenic or beneficial organisms. Heavy metal content was analyzed to ensure compliance with recommended safety standards. The estimation of all the parameters was done for both untreated and rice husk biochar treated water to understand the changes to determine the treatment efficacy.

**3.1 Physical Parameters:** The pH, Temperature, Conductivity and Turbidity were measured using a pH meter, thermometer, conductivity meter and turbidity meter according to standard protocols.

Total solid (TS), total dissolved solid (TDS), total suspended solid (TSS) content was measured by gravimetric method and calculated applying the standard formula.

### 3.2 Chemical Parameters:

**Lignin Estimation:** 50 mg of CBBG (Coomassie Brilliant Blue G-250) was mixed into 25 ml of ethanol, followed by 50 ml of phosphoric acid and 20 ml of distilled water. After filtration, a 15 ml CBBG solution was mixed with 5 ml of rice mill effluent and the absorbance was measured at 540nm.

**Phenol Estimation:** 5 mL rice mill effluent is mixed with 2.5 ml Folin-Ciocalteu reagent and 15 ml Sodium carbonate solution (7.5%), and the absorbance was

measured at 765 nm against gallic acid standard curve.

**Sulphate Estimation:** It was estimated by preparing 10 ml rice water and adding 4 ml buffer (0.3 g magnesium chloride (MgCl<sub>2</sub>.6H<sub>2</sub>O), 0.05 g sodium acetate (CH<sub>3</sub>COONa.3H<sub>2</sub>O) and 0.01 g potassium nitrate (KNO<sub>3</sub>), 0.2 mL acetic acid (CH<sub>3</sub>COOH; 99%) in 5 mL distilled water) Then 0.3 g bac12 stir was added and the absorbance was measured at 420 nm.

**Phosphate Estimation:** It was estimated by adding one drop of phenolphthalein indicator to the sample and then a few drops of 5(N) sulphuric acid to remove the colour. Next, 8 ml of mixed solution [50 ml 5 (N) Sulphuric acid with 15 ml (4g of ammonium molybdate in about 20 mL distilled water) and 30 ml (1.25 g fresh SnCl<sub>2</sub> in 50 ml glycerol)] was added. The solution was incubated at room temperature for 30 mins and the absorbance was measured at 890 nm.

**Estimation of Chemical Oxygen Demand (COD):** COD estimation was done by using standard titrimetric method using K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> and H<sub>2</sub>SO<sub>4</sub> and the subsequent calculation against a blank was done following the formula.

**3.3 Heavy Metal Estimation:** Heavy metal analysis was performed by acid digestion with HNO<sub>3</sub> using a hot acid extraction procedure, following the Apha 24th edition (2023) method and quantified with a Flame Atomic Absorption System.

**3.4 Estimation of Microbial Load:** The microbiological study was done by performing dilution, consecutive staining and biochemical tests for colony identification. The development of different bacterial colonies under the same

incubation condition with the use of culture-based technique was used as the method for understanding the difference between the treated and untreated samples. The growth tendency of the microbes was determined qualitatively by counting the visible presence of the bacterial colonies.

**Statistical Analysis:** All experiments were conducted in triplicate (n=3). The data is expressed as Mean ± Standard Deviation.

## 4) Results

Assay of all the initial parameters were started within 24 hours of collection of the water sample. The next set of data was generated after performing the filtration process using rice husk biochar. A considerable amount of change was observed with percentage decrease in different parameters as shown in the table 1, validating the treatment process. The pH of the sample water was acidic initially which became neutral after treatment.

Table 1: Percentage of change in different physicochemical parameters after biochar treatment

Parameters	% Change
Conductivity	66.21%
Turbidity	90.38%
TDS	64.70%
TSS	74.02%
Lignin	57.40%
Phenol	61.62%
Sulphate	65%
Phosphate	36.15%
COD	26.18%

Results of total solids, total dissolved solids and total suspended solids as shown in

fig.1, reveal a 1/3 decrease after treatment, which reflects improvement in the quality of water and adsorption efficiency of biochar used in the treatment.

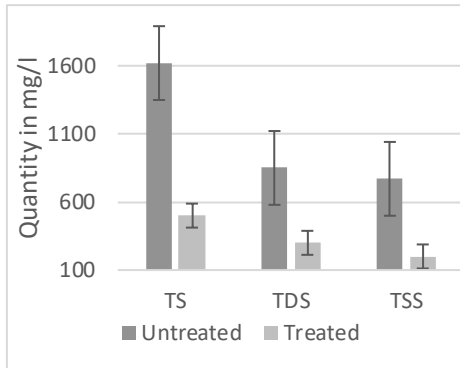


Fig.1. Depiction of changes in the physical parameters between initial and final results

Treatment of rice mill water with biochar has resulted in gradual decrease in different parameters as shown in fig.2, with reduction in lignin content, 57%, in phenol and sulphate content 61.62% and 65% respectively. The phosphate and COD content also decreased. The COD reduction is comparatively low might be due to high concentration of other metals & minerals which has interfered with the adsorption capacity of the biochar.

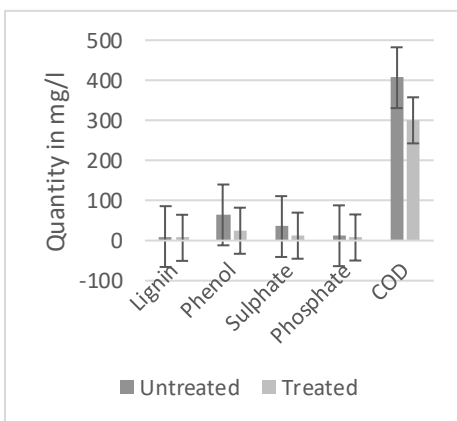


Fig.2. Depiction of changes in the chemical parameters between initial and final results

The decrease in heavy metal content as in fig.3 shows variation of initial concentration of 3.1 mg/l iron, 2.31 mg/l zinc, 75.6 mg/l arsenic, 41 mg/l nitrogen with final concentration of 2.56 mg/l iron, 1.19 mg/l zinc, 38 mg/l arsenic and 31.93 mg/l nitrogen after biochar treatment showing maximum of 49% change in arsenic content, 48% decrease in zinc content, iron and nitrogen content showing a decrease of 17% and 22% respectively. This variable adsorption can be contributed to the charge and size of the ion.

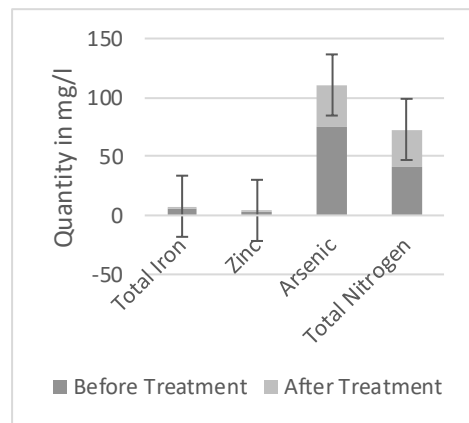
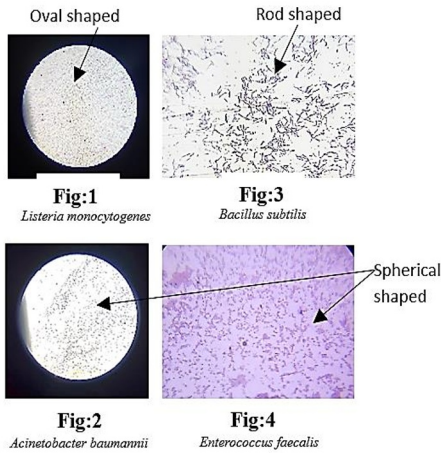


Fig.3. Depiction of heavy metal trends between initial and final result

### Microbial analysis

The untreated wastewater from the rice mill exhibited a substantial microbial load ( $10^{10}$  CFU/mL), predominantly consisting of highly pathogenic bacteria such as *Listeria monocytogenes* (Fig:1) and *Acinetobacter baumannii* (Fig:2), indicating severe contamination. Following treatment, the microbial count decreased to  $10^7$  CFU/mL, with a lower number of pathogenic bacteria and a shift towards less harmful species, including *Bacillus subtilis* (Fig:3) and *Enterococcus faecalis* (Fig:4), demonstrating an enhancement in microbial quality and effective pathogen control.



## 5) Discussion

This study emphasizes biochar as an effective and sustainable material for enhancing the reusability of wastewater from rice mills. Biochar improved the removal of persistent organic pollutants like lignin and phenolic compounds by utilizing its porous structure and functional surface groups. It also significantly improved important physicochemical parameters like COD, TDS, and dissolved oxygen levels [5]. Activated biochar was reported to be efficient material to remove various contaminants, inorganics such as heavy metals also pathogenic organisms [6]. The results indicate that adsorption of trivalent ions like arsenic, iron is more effective than that of bivalent ion zinc, while adsorption of nitrogen is lower, likely because of its negative ionic charge. In a study on the competitive adsorption behaviour of bivalent metal ions in wastewater on biochar, it has been found that  $Pb^{+2}$  has better adsorption than  $Cu^{+2}$  and then  $Zn^{+2}$  might be due to its size [7]. Species like *Acinetobacter junii* has high capacity for biodegradation [8] of rice mill

effluent but our water sample consists of *Listeria monocytogenes* and *Acinetobacter baumannii* which do not support biodegradation of rice mill effluent thus reduction in the parameters observed might be due to the biochar-based adsorption of contaminants. According to WHO water quality standards [9], the pH level should be within 6.5-7.8, turbidity must be <5 NTU and conductivity <250  $\mu\text{s}/\text{cm}$ , TDS <500 ppm, COD <250 mg/l with respect to this the results showed pH of 7, turbidity and conductivity of 3.8 NTU and 67.4  $\mu\text{s}/\text{cm}$ , TDS and COD of 300 ppm and 300 mg/l respectively which makes it suitable for irrigation purpose. In the present work all the parameters apart from COD are within acceptable limits. The slight difference in COD value may be due to an excess load of other contaminants

## 6) Conclusion

The overall results showed that use of biochar can be an environment friendly and cost-effective choice for treating rice mill effluent. Biochar used in present research is by utilising the rice mill waste (rice husk) hence, there is no raw material cost involved. The pyrolysis was done in a comparatively low temperature ( $350^{\circ}\text{C}$ ) in a moderate furnace which makes the process further cost effective and easy preparation process. Using 100 g of rice husk-based biochar can filter approx. 1 litre of water. However, the column filtration method is time sensitive hence for large scale application some improvisation needs to be developed.

## 7) References

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