Waste to Wealth Approach: Removing Toxic Heavy Metals and Organic Dyes from waste Water using Agricultural Waste

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Abstract— The application of bioadsorption in drinking water treatment and pollution cleanup is promising, as demonstrated by a number of field-based (pilot and full scale) and bench scale studies. A direct comparison between traditional treatment technologies and emerging approaches (use of agricultural waste) using nanotechnology is needed. In this paper, the performances of traditional technologies and nanotechnology for water treatment and environmental remediation were compared. The technological trend towards waste utilization and cost reduction in water purification industries has attracted use of Rice Husk as a value added material. By using the modified rice husk, remediation of waste water can be done by removing toxic heavy metals such as Cd, Cu, Hg, Cr, Pb, Zn and Ni and organic dyes from it. The application of rice husk for waste treatment can evolve as economically sustainable and environmentally friendly approach to remove toxic metals from water.

Keywords— Agricultural Waste, Nanosilica, Water purification, Waste water treatment.

I. Introduction

In today's progressive world increasing use of heavy metals, organic dyes, *etc*. are responsible for universal distress as they are disposed toxins responsible for environmental degradation. Consistent with the United Nations organization (UNO) surveys most of the countries have limited sources of pure water and results in extensive health hazards due to water pollution [1],[2]. Waste effluents from various industries such as alloy manufactures, automobile exhausts, fossil fuel combustion, fertilizers, pesticides, metal plating, mining, pyrometallurgical, smelting, storage batteries, tanneries, research laboratories, *etc*. triggers environmental degradation and water pollution. Heavy metals like arsenic, cadmium , copper, lead, nickel, zinc, *etc*. and dyes such as Crystal violet (CV), EDTA, Methylene blue (MB), Methyl orange (MO), *etc*. are the most common pollutants found in industrial sewages[2],[3]-[4]. Millions of tons of discharged dyes and heavy metals effluent enters into water sources and turn out to be hazardous for the marine lives [5]. The stability, small size as well as non-biodegradable characteristics of the pollutants make them invincible to be removed from polluted water [6]. Hence, there is a great demand to treat the contaminated wastewater preceding its release in the environment. Organic dyes and heavy metals are abolished from waste water solutions using altered polymeric materials having surface active functional groups [7],[8]-[9]

One of the best solutions of the problem is the use of rice husk, an agricultural waste. All over the world rice production is the highest cultivating food crop and produces an enormous amount of waste, commonly known as rice husks (RHs). On burning RH liberates poisonous CO_2 gas, therefore it can be utilized in generating activated carbon (AC) [10], silica [11] and nanosilica [12] due to high carbon content (~39%). In this paper we have exploited the concept "waste to wealth" and purified the laboratory discarded water using agricultural waste- rice husk. We have also employed RH in generating activated carbon, silica and nanosilica from the same. We have discovered that all these bioadsorbents are capable in cleaning polluted water; nano-silica predominates over silica and activated carbon in removing pollutants.

II. MATERIALS AND METHODS

A. *Materials*

The raw material was obtained from a rice mill of Muzaffar Nagar, Uttar Pradesh (India). All reagents used in the present study were of analytical grade and the stock solutions were prepared in milli pore water. Laboratory grade HCl, H_2SO_4, and NaOH were procured from Merck.

In quest of our study for exploration of adsorption capacity of rice husk; we extracted silica from RH. For extraction of silica various methodologies given by various chemists were tested. However, by applying certain modifications in some of the steps, maximum yield of silica from rice husk was obtained.

B. *Methods*

a) W*ashing and acid treatment*: RH was washed thoroughly with water to remove the soluble particles, dust, and other contaminants present, whereby the heavy impurities like sand,

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stones, *etc*. are also removed. Rice husk was then filtered through ordinary kitchens sieve. It was then dried in an oven at ~110°C for 24 hours. The dried RH was ultrasonicated with an acidic solution of HCl for nearly 30 min by continuous stirring. It was cooled and kept intact for ~20 hours. It was then decanted and thoroughly washed with warm distilled water until the rinse became free from acid, and this was designated as RH'. The wet RH' was consequently dried in an oven at 110°C for 24 hours.

b) *Thermal treatment*: A weighed RH' as well as RH were subjected to heat treatment to obtain the ash. Samples were burned inside a programmable furnace (Metrex programmable furnace) (500°C, 700°C, and 1,000°C), and rates (2°C/min, 5°C/min, and 10°C/min) were checked. We designated these as ashes (RHAs).

c) *Extraction of silica*: A sample of 20 g RHA was stirred in a 160 mL, 2.5 M NaOH solution. The solution was heated in a covered beaker for 3 hours by stirring constantly. The contents were filtered and the residue was then washed with 40 mL of boiling distilled water. The obtained viscous, transparent, and colorless solution was allowed to cool down to room temperature, and 10 M H_2SO_4 was then added under constant stirring at controlled conditions until it reached pH 2; NH_4OH was added to maintain pH 8.5 and was allowed to stand at room temperature for 3 hours.

d) *Preparation of nanosilica*: Nanosilica was prepared by refluxing the extracted silica with 6.0 M HCl for 4 hours and then washed repeatedly using deionized water to make it acid free. It was then dissolved in 2.5 M NaOH by vigorous stirring. H_2SO_4 was added until pH 8 was attained. The precipitated silica was washed repeatedly with warm, deionized water to make it alkali free and then dried at 50°C for 48 hours in the oven.

III. RESULTS AND DISCUSSION

Characterization: After acid treatment and controlled combustion, 25% of RHA was produced. The color of both RHA and nanosilica was white. Fig. 1 shows the FTIR spectra of extracted silica and nanosilica. The band at 570 cm^{-1} is due to the bending frequency of Si-O-Si. The peaks at 1062 cm^{-1} are due to the Si-O-Si asymmetric and symmetric stretching modes, respectively. A band at 1616 cm^{-1} is assigned to the bending vibration of water molecules bound to the silica matrix. A broad band ~3438 cm^{-1} is attributed to the presence of the O-H stretching frequency for the Si-OH group and the remaining adsorbed water. No peak was found between 2,800 to 3,000 cm^{-1}, which indicates the absence of other organic compounds in the silica after controlled combustion and extraction.

For further clarification, the XRD data was examined (Fig. 2). The diffraction peak at 2θ = 22° degree confirms the formation of amorphous silica. The lack of sharp peaks reveals the absence of crystalline phase [13].

The chemical stability, high mechanical strength, and granular structure of pretreated RH make them effective adsorption material for eliminating toxins (heavy metals & organic dyes) from waste water. By exploiting RH, remediation of waste water was done by removing toxic heavy metals such as Cr, Mn, as well as dyes like Crystal violet (CV), Rhodamine-B (Rh-B) from it.

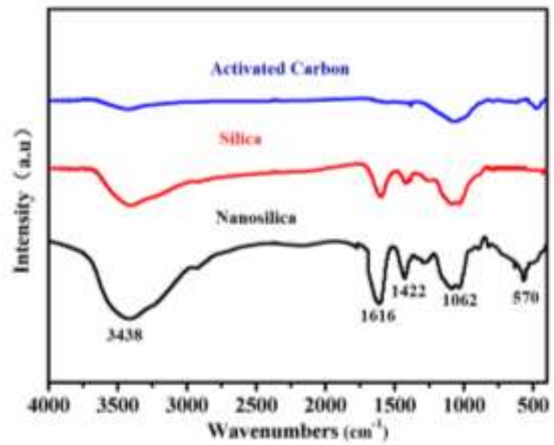


Fig. 1: FTIR spectra of silica and nanosilica.

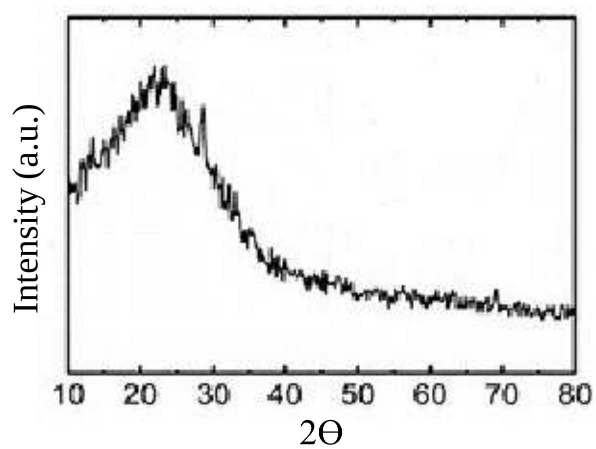
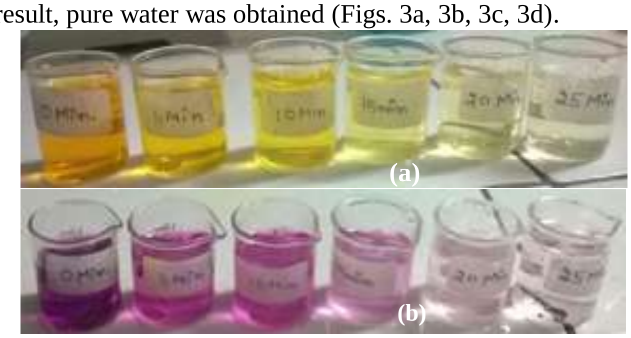


Fig.2: Powder XRD pattern of nanosilica.

Purification of waste water using batch process with different adsorbents: In order to show the excellence of this protocol, commercial activated carbon, ordinary silica, and nanosilica, respectively were taken in 100 cc beaker and then 20 mL stock solution of heavy metal and dyes were taken in it. Metal ions and dyes bound with the different adsorbents; as a result, pure water was obtained (Figs. 3a, 3b, 3c, 3d).



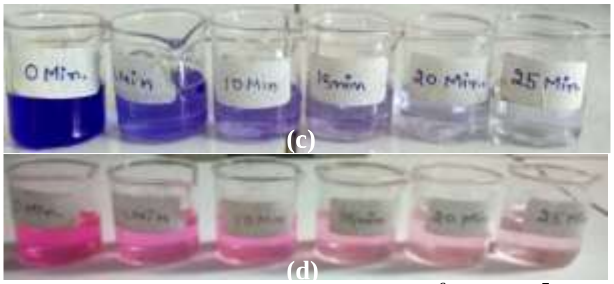


Fig 3: Adsorption of contaminants, a) Cr^{6+}, b) Mn^{7+}, c) CV, d) Rh-B) on nanosilica with time .

UV-Vis Spectrophotometric measurements: For verifying the validation of this method absorbance measurements were done on Motras Scientific spectrophotometer. The absorbance of contaminated water containing heavy metals like Cr^{+6} (solution polluted from $K_2Cr_2O_7$, Fig. 4), Mn^{+7} (contaminated solution of $KMnO_4$, Fig. 5); and organic dyes namely, CV (Fig. 6) and Rh-B (Fig. 7) using different adsorbents were recorded.

From the data (Figs. 4-7), it was found that the absorbance of all the contaminated solutions was decreased upon addition of adsorption materials. This implies that the concentration of the impurities in the solution was reduced upon biosorption as heavy metals got trapped on their surfaces.

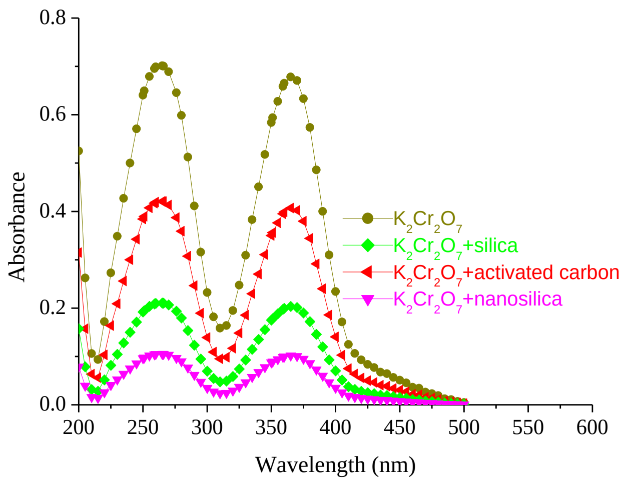


Fig. 4: Absorbance values of different adsorbents on $K_2Cr_2O_7$.

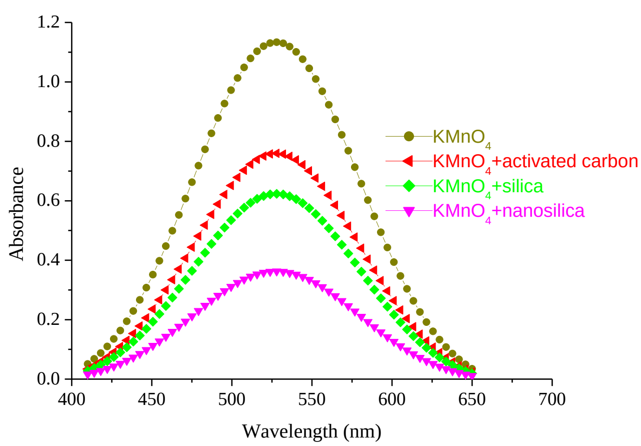


Fig. 5: Absorbance values of different adsorbents on $KMnO_4$.

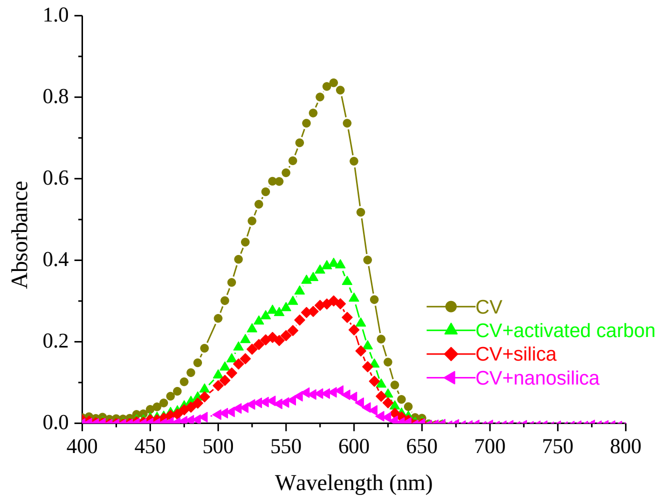


Fig. 6: Absorbance values of different adsorbents on CV.

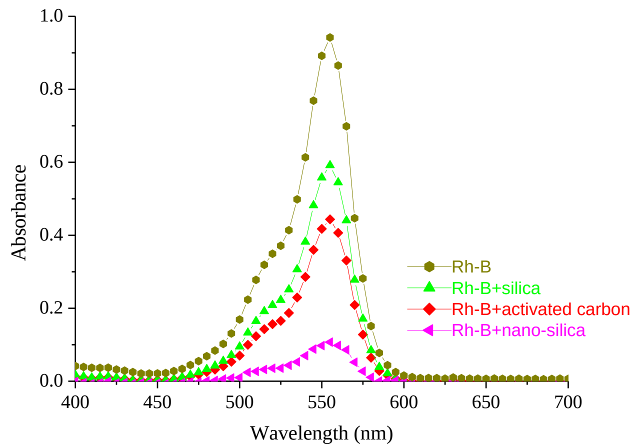


Fig. 7: Absorbance values of different adsorbents on Rh-B.

From the graph it was found that the nanosilica prepared from agricultural waste (rice husk) has given best results for the adsorption of heavy metals and organic dyes.

IV. Conclusion

This environmental friendly methodology promises several attracting features for the treatment of waste water. The application of rice husk for waste treatment can evolve as economically sustainable and environmentally friendly approach to remove toxic metals from water and soil. Waste to wealth becoming can be well emphasized by this paper.

Acknowledgment

The authors (P. Malhotra, A. Jain and R. Payal) are thankful to university of Delhi, New Delhi for their financial assistance.

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