Adsorption of arsenate from aqueous solution by rice husk-based adsorbent

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Abstract. Rice husk-based adsorbent (RHBA) was prepared by burning rice husk in a muffle furnace at 400°C for 4 h and adsorption of arsenate by the RHBA from aqueous solution was examined. Batch adsorption test showed that extent of arsenate adsorption depended on contact time and pH. Equilibrium adsorption was attained in 60 min, with maximum adsorption occurring at pH 7. Equilibrium adsorption data were well described by the Freundlich isotherm model. Freundlich constants $K_f$ and $1/n$ were 3.62 and 2, respectively. The RHBA is effective in the adsorption of arsenate from water and is a potentially suitable filter medium for removing arsenate from groundwater at wells or in households.

1. Introduction

Arsenic is a highly toxic element and historically has been used as a poison [1]. Due to its toxicity and mobility, water pollution due to arsenic contamination has gained attention of the world and has been recorded by the World Health Organization (WHO) as a top priority issue. Arsenic in the aquatic environment is primarily present in the form of two inorganic species (arsenate and arsenite) and arsenate [(As (V))] is the predominant form of arsenic in oxidizing conditions [2]. The presence of arsenic in the natural water is due to the process of leaching from the arsenic containing source rocks and sediments [3,4]. More recently, arsenic has been used as an insecticide, fungicide, rodenticide and wood preservative. The common applications of arsenic are in the manufacture of pesticides, desiccants, glass, alloys, electronic components, pigments and pharmaceuticals, which create additional arsenic problems [5]. The presence of arsenic in drinking water even at low concentrations poses a threat to human health, as arsenic is a well-known toxic element and a documented human carcinogen. Long-term exposure to arsenic via drinking-water causes cancer of the skin, lungs, urinary bladder and kidney as well as other skin changes such as pigmentation and thickening (hyperkeratosis) [6]. Millions of people worldwide are exposed to naturally occurring arsenic-contaminated groundwater, which they use as their only source of water [7]. A number of large aquifers in various parts of the world have been identified with problems from arsenic occurring at high concentrations. The most noteworthy occurrences are in parts of West Bengal (India) and Bangladesh, Taiwan, northern China, Hungary, Mexico, Chile, Argentina and many parts of the USA [8] and Vietnam [9]. According to WHO and the United States Environmental Protection Agency (US EPA), the maximum allowable concentration of arsenic in drinking water is 10 µg/L. However, in many parts of the world arsenic concentration about 100 times more than the permissible limit is found. According to a WHO survey conducted in 2006, the number of people toxified by arsenic in India and Bangladesh alone are about 700 million, which might be the largest poisoning in the world history [10 - 12]. Several
techniques such as solvent extraction, chemical precipitation as synthetic coagulants, ferrihydrite precipitation, iron co-precipitation, ion exchange and reverse osmosis can be used to remove arsenic from water. However, the disadvantages associated with these techniques are incomplete metal removal, high cost of reagent and energy requirements [13]. There is an urgent need for low-cost adsorption medium for removing arsenic from drinking water and to reduce arsenic concentration in food grains.

In the present study, rice husk-based adsorbent (RHBA) was prepared from rice husk and adsorption of arsenate [(As (V))] by the RHBA from aqueous solution was examined.

2. Materials and methods

2.1. Preparation of RHBA
Rice husk was cleaned several times with distilled water in order to remove the dust and dried in an oven at 105°C for 24 h. The cleaned and dried rice husk was then subjected to burning in a muffle furnace at a temperature of 400°C for 4 h. The resulting rice husk-based adsorbent was ground to a size of 200-500 µm and used in batch adsorption test.

2.2. Batch adsorption test
Batch adsorption test was carried out by shaking 100 mL of arsenate solution of desired concentration with RHBA in conical flasks at room temperature (22°C) using an orbital shaker at 150 rpm. After a predetermined contact time, a flask was removed from the orbital shaker and the supernatant was filtered through 0.45 µm membrane filter and analysed for residual arsenate concentration. The effects of contact time, initial arsenate concentration, pH and RHBA dose on adsorption were determined. The pH of the solution was adjusted by 0.1 N NaOH or 0.1 N HCl. Adsorption isotherm was determined by batch equilibrium test using optimum contact time and pH for adsorption of arsenate by RHBA.

3. Results and discussion

3.1. Characterisation of RHBA
The values of BET surface area, micropore area, micropore volume and average pore diameter are 134.5 m²/g, 2.75 m²/g, 0.000392 mL/g, and 78.11 Å, respectively. Scanning electron micrograph of RHBA (Figure 1) shows presence of macro- and micro-pores.

![Figure 1. Scanning electron micrograph of RHBA](image)

3.2. Effect of pH
The effect of pH on arsenate adsorption by RHBA was studied in the initial pH range between 5-9 with contact time of 24 h and the results are shown in Figure 2. Maximum adsorption of
89% from a 0.1 mg/L arsenate solution by 1 g/L RHBA dose was achieved at pH 7. All subsequent adsorption tests were conducted at pH 7.

![Figure 2. Effect of pH on adsorption of arsenate by RHBA](image)

3.3. Effect of contact time and initial concentration

Effect of contact time and initial arsenate concentration on adsorption by RHBA is shown in Figure 3. The contact time was varied in the range 5-120 min at arsenate concentration 0.1, 0.15, 0.2 and 0.25 mg/L, RHBA dose of 1 g/L and pH 7. Equilibrium was attained in 60 min. A contact time of 60 min has also been reported by Bhattacharya et al. [14] for the adsorption of arsenate by uncalcined and calcined aluminium hydroxide powder. A contact time of 60 min was used in all subsequent adsorption tests.

![Figure 3. Effect of contact time on adsorption of arsenate by RHBA](image)

3.4. Adsorption isotherm

Equilibrium arsenate adsorption data were fitted to the linear form ($\log q_e = \log K_f + 1/n \log C_e$) of the Freundlich adsorption isotherm (Figure 4). The values of Freundlich constants $K_f$ and $1/n$ for arsenate RHBA were found to be 3.67 and 2, respectively.
4. Conclusions
Rice husk-based adsorbent was found effective in the adsorption of arsenate (As(V)) from aqueous solution and maximum adsorption occurred at pH 7. Equilibrium was attained in 60 min and equilibrium adsorption data were well described by the Freundlich isotherm model. Freundlich constants $K_f$ and $1/n$ were 3.67 and 2, respectively. Being a low-cost agricultural by product, the rice husk-based adsorbent can be implemented as an effective adsorbent for arsenate removal from groundwater at wells or in households.

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