



## Phenol Removal from Aqueous System by Jute Stick

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### Abstract

The adsorption technique using jute sticks has been applied for the removal of phenol from aqueous solutions. The extent of removal was dependent on concentration of phenol, contact time, pH, and quantity of adsorbent. With an initial concentration of 40 ppm phenol in 100 mL and pH 10.0, the removal was found to be about 68% with 3.0 g jute stick. The time to reach equilibrium was found to be 5 hr. The applicability of Freundlich isotherm to the adsorption of phenol system was tested at 25 °C to 40 °C at pH 10.0. The spent adsorbent was regenerated by acid treatment.

**Keywords:** Removal; Phenol; Jute stick; Batch system; Freundlich isotherm.

### Introduction

Phenolic compounds which are generated from petroleum and petrochemical, coal conversion, and phenol-producing industries, are common contaminants in wastewater and suspected as toxic and carcinogenic. Therefore, phenol and phenolic compounds were designated as priority pollutants by the US EPA, which take the 11<sup>th</sup> place in the list of 129 chemicals [1]. Also the European Union (EU) has classified several phenols as priority contaminants and the 80/778/EC directive lays down a maximum concentration of 0.5 µg L<sup>-1</sup> for total phenols in drinking water [2]. Apart from their toxicity and carcinogenicity, phenols can cause bad taste and odor, even at low concentration [3]. For this reason it is necessary to eliminate phenols from wastewater before it is discharged.

Various treatment technologies such as adsorption [4–6, 21, 22], photodegradation [7], flocculation [8], chemical oxidation [9, 23, 24], biological process [10], etc. are available for the removal of phenol from the wastewater. Biological process is particularly suited to wastewater containing small amount of phenol. Oxidation is used when phenol concentration in wastewater is very high. In coagulation and flocculation process, large amount of sludge is generated which may cause disposal problems. Among various physicochemical processes, adsorption is widely used for the removal of phenol from wastewater [4,11]. Literature on the adsorption of phenolic compounds

onto activated carbon is abundant [12–14]. Due to the relatively high cost of activated carbons there have been attempts to utilize low cost, naturally occurring adsorbents include straw, auto mobile tires, fly ash, coal reject, sewage sludge, bagasse, fertilizer waste and saw dust [15–19] to remove organic pollutants. However, the adsorption behavior of phenol on jute stick has not so far been extensively studied. The present study is intended to use of this locally available as a conventional cheap material as a phenol adsorbent.

### Experimental Materials and Method Adsorbent

The jute sticks were carefully collected without any contamination from local area. After collection, jute sticks were treated to make them ready for use. The jute sticks were dried initially in an oven at about 70 °C and then ground to fine mesh and the particles size of 177–62 µm were separated by sieving through standard test sieves. Then these were boiled in distilled water continuously for 30 minutes. The suspension was then left to settle to allow the supernatant to be poured off. This process was repeated several times until the coloured water-soluble components were removed completely. Finally the washed adsorbent was dried in an oven at 80 °C, allowed to cool and sieved into 177–62µm for subsequent use.

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### Chemicals and apparatus

All the reagents and chemicals used were of A. R. Grade (BDH). The solutions were prepared in double distilled water. A stock solution of phenol was prepared by dissolving 0.5g phenol in 500mL capacity volumetric flask. This was treated as stock solution of phenol (1000ppm). The phenol estimation was done spectrophotometrically by the 4-aminoantipyrine method using Shimadzu UV-160 double beam spectrophotometer [20]. Buffer solutions of different pH values procured from E. Merk (Germany) were used to keep the pH of the solution fixed at a definite value. pH of the substrate was determined using a microprocessor bench pH meter (HANNA pH 300).

### Estimation of phenol by modified method

The 4-aminoantipyrine method gave unsatisfactory result [20]. So attempts were made to modify the 4-aminoantipyrine method. Preliminary experiments showed that phenol does not give any appreciable colour with 4-aminoantipyrine in presence of potassium ferricyanide in acidic medium. But at pH 8.0 phenol gives a deep brownish red colour whose intensity gradually increases up to pH 10.0 and then sharply decreases. This colour system was made the basis for the development of the modified spectrophotometric method for the determination of trace amount of phenol at a pH 10.0 instead of pH 8.0. Absorbance measurements, carried out against reagent blanks, revealed that the absorption maxima is at 497 nm and that the time required for full colour development is 40 minutes. Experimental result revealed that 2 mL of 2.0% (w/v) 4-aminoantipyrine solution is sufficient for the development of maximum colour intensity of the system containing 40 ppm phenol solution. Results of the effect of potassium ferricyanide indicates that 6.0 mL of 8.0% of (w/v) potassium ferricyanide solution is the optimum amount for the development of the maximum colour intensity of the system containing 40 ppm phenol solution. The colour intensity of system under investigation was unaffected by variation in temperature from 25 to 40 °C. It was also observed that the colour intensity gradually decreases beyond this range. It was found that the modified method was more suitable.

### Removal of phenol from aqueous solution

**Batch adsorption:** The batch experiments were conducted using 1.0g of adsorbent in 250mL capacity stopper bottles with 100mL of phenol solution. The adsorbate concentrations were varied in the range of 10–60ppm. The whole study was carried out at pH 10.0, at higher pH the texture of the adsorbent is changed. The

bottles were then shaken at uniform speed at room temperature using an electric shaker. However, experiments at higher temperatures were carried out in beakers in a thermostatically controlled water bath using electrical stirrer. At predetermined time intervals the contents were centrifuged and the remaining concentration of phenol in the supernatant were analyzed spectrophotometrically against respective reagent blank. The bottles containing phenol of different concentration and the specified pH, were shaken for 6 hours to ensure complete saturation. The amount of phenol adsorbed was determined from the difference between the amount of phenol initially added and that left after adsorption. Batch experiments were also performed to study the effect of temperature at (25, 30 and 40°C) on adsorption of phenol by jute sticks. Interestingly, temperature (25<sup>o</sup>–40<sup>o</sup>C) had no appreciable effect on the adsorption of phenol and thus all subsequent experiments were carried out at room temperature. The concentration range of phenol adhering to Beer's law under the conditions of investigation for the system was 10–60ppm.

## Results and Discussion

### Effect of concentration and contact time

Batch experiments were carried out to investigate the effect of phenol concentration on the extent of adsorption as a function of time for the initial phenol concentration of 10, 40, 50 and 60 ppm which is shown in Fig. 1.

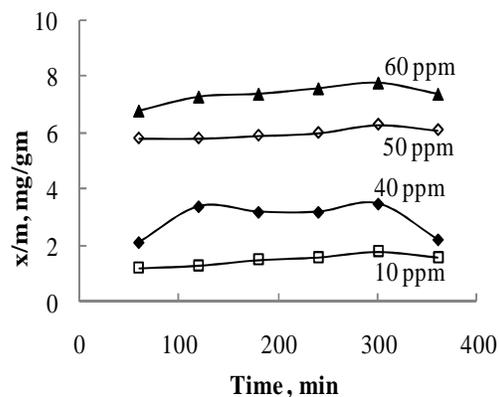


Figure. 1. Effect of initial concentration and contact time on phenol removal

The percentage removal of phenol and phenolic compounds as well as the adsorption-desorption behavior were also varied. The maximum percentage of phenol removal took place within 5 hours. The equilibration time is independent of concentration and hence this period was chosen for further equilibrium batch adsorption studies.

### Adsorption isotherm

The adsorption behavior of phenol on jute sticks at all temperatures was in close agreement with the Freundlich equation. The constants  $K_F$  and  $n$  obtained from the linear regression analysis of

$$\log x/m = \log K_F + 1/n \log C_e$$

The intercept  $\log K_F$  is roughly an indicator of sorption capacity and the slope  $1/n$  is adsorption intensity. Results of jute sticks are graphically presented in Fig. 2.

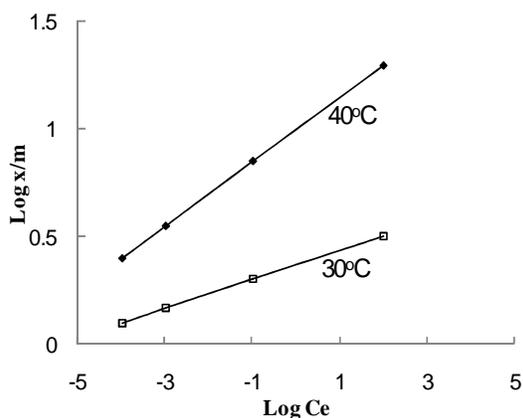


Figure 2. Freundlich adsorption isotherm

### Effect of Temperature

Temperature is an important parameter for any separation process. Removal of phenol by jute sticks was studied at four different temperatures: 25, 30, 35 and 40 °C. It was found that the temperature in the range of 25–40 °C had no effect on the phenol removal. Therefore all subsequent experiments were carried out at room temperature.

### Effect to pH

The removal of phenol from the wastewater is highly dependent on pH of the solution. pH affects the surface charge of the adsorbent and degree of ionization and specification of phenol. The uptake with 40 ppm phenol is small at low pH ranges and gradually increases up to pH 10.0, where maximum removal 68% occurs. Thus 10.0 pH was chosen as the optimum and all the subsequent experiments were carried out at this pH. As was expected, the adsorbed amount decreases with increasing the pH value. This can be attributed to the dependency of phenol ionization on the pH value. The ionic fraction of phenolate ion increases as the pH value increased. Accordingly, phenol, which is a weak acid ( $pK_a=10$ ), will be adsorbed to a lesser extent at

higher pH values due to the repulsive forces prevailing at higher pH values. Similar behavior has been reported for the adsorption of phenol by activated carbon [13].

### Regeneration

0.5 g of spent adsorbent after adsorption at pH 10.0 was washed with distilled water to remove any adhering phenol and was shaken with 100mL of 0.1M HCl for regeneration which was completed within 30 minute duration. About 68% of the adsorbed quantity of phenol from the initially present 40ppm was desorbed from all the samples in a single step. It was then washed with distilled water dried in a hot air oven and was reused in subsequent operations. In this way after regeneration samples can be reused in the operation. It reduces the operation cost and thus may be very useful.

### Optimum quantity of adsorbents

The amount of jute sticks taken were 0.5, 1.0, 1.5, 2.0, 2.5, 3.0 and 4.0 g to determine the optimum quantity of jute sticks. The amount of reagents and chemicals added were kept unchanged and pH was also maintained at 10.0. From the adsorption data, it was found that adsorption is completed within 5 hr and the percentage of adsorption increases with the increasing amount of jute stick. The highest percentage of adsorption was obtained by using the 3.0g of jute stick. Therefore, optimum quantity was found to be 3.0g which is shown in the Table 1.

Table 1. Optimum quantity of jute stick

| Amount of jut stick (gm) | Adsorption (%) |
|--------------------------|----------------|
| 0.5                      | 54.35          |
| 1.0                      | 59.78          |
| 1.5                      | 61.86          |
| 2.0                      | 63.87          |
| 2.5                      | 65.96          |
| 3.0                      | 67.69          |
| 4.0                      | 67.68          |

### Conclusion

The present study shows that the jute stick is an effective adsorbent for the removal of phenol from aqueous solutions. Moreover, in the context of the present efforts for the diversified uses of jute, a new field will be opened if jute sticks are taken as adsorbents. Jute stick can be used as an adsorbent for phenol removal in a wide pH range of 6–12. Under

batch conditions equilibrium was attained in 5 h. Maximum removal of phenol was obtained with 3.0 g jute stick at an initial pH of 10.0. The Freundlich isotherm show very good fit with the experimental adsorption equilibrium data.

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