The Decolorization and Phytotoxic Efficiency of Jackfruit Seed on a Textile Dye Novacron Blue

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ABSTRACT

Industrial wastewater containing dye can cause severe destruction to the human immune system as well as the nervous system. The purpose of the present study is to optimize the decolorization of a textile dye Novacron blue on the surface of jackfruit seed powder (JSP). Jackfruit seed can be obtained at a low cost and be used without further purification/chemical treatment to adsorb some pollutants on its surface. About 73% of Novacron blue was adsorbed on the surface of JSP after 60 minutes of contact time. Effects of various physico-chemical parameters such as adsorbent dose, initial dye concentration, pH, temperature, and contact time on the adsorption of Novacron blue have been investigated. The adsorption was found to be increased initially with the adsorbent dose and become maximum at 10 g of the adsorbent. The maximum adsorption capacity was 0.732 mg/g. The decolorization efficiency was inversely proportional to the initial concentration of Novacron blue. Basic medium and low temperature are preferred by the adsorbent for the adsorption of Novacron blue on JSP. Kinetics of adsorption was accomplished with the pseudo-first-order and pseudo-second-order model. Phytotoxic study on Red Amaranth reveals the abolishment of hazardous species from the wastewater.

Keywords: Adsorption, Bio-adsorbent, Decolorization, Jackfruit Seed, Phytotoxic Efficiency.

1 Introduction

Dyes are aromatic synthetic compounds that are colorants and water-soluble. These are used as raw materials in various industries such as leather, paper, pulp, paint, cosmetics, printing, textile, etc [1]. Dye is one of the hazardous and abundant water pollutants among the various organic compounds [2]. The textile industry utilizes over 7×10^5 tones and about 10000 different dyes and pigments per year [3]. Improper discharge of industrial dye effluent causes severe damage to the environment. These are visually unpleasant in the aqueous environment and cause a reduction in sunlight and oxygen penetration by their high turbidity. For this reason, photosynthetic activity, dissolved oxygen concentration as well as water quality is decreased. In addition dye molecules increase the total organic carbon (TOC) and decrease the chemical oxygen demand (COD) and biological oxygen demand (BOD) in the water system. Furthermore, several reports indicate that textile dyes and effluents have toxic effects on the germination rates and biomass of several plant species which have important ecological functions [2],[4]-[6].

So, the treatment of effluent-containing textile dye is crucial before their final discharge to the environment to protect aquatic life and public health. Numerous methods like ozonation, photo-oxidation, electrocoagulation, froth flotation, reverse osmosis, ion exchange, membrane filtration, flocculation, and adsorption by activated carbon are applied for color removal from effluents containing textile dye [2],[7]-[9]. Adsorption is widely used for the removal of wastewater due to the ease of its operation and cost-effectiveness. But the use of commercially available activated carbon/chemicals as adsorbents is expensive for their manufacturing and regeneration costs [10]. Using biological materials as adsorbents is found to be superior to other techniques for its cost-effectiveness, higher efficiency, less

sludge production, minimal requirement for chemicals, etc. Some cost-effective bio-adsorbents such as rice husk, sawdust, orange peel, water hyacinth, peanut hull, pomegranate seed, neem leaf powder, wheat straw, apple pomace, de-oiled soya, palm ash, aloe vera leaf, durian peels, banana peel and have been used for removal of dye from wastewater containing industrial effluent [2],[7]-[8],[11]-[24]. For instance, the decolorization of crystal violet (91.1%) and methylene blue (83.6%) by seed powder of *Punica granatum* L at neutral pH have been reported [24]. The maximum adsorption capacity of Jackfruit seed on Rhodamine B was found to be 26.4 and 37.9 mg/g, respectively by Langmuir and Sips models prediction [25]. The maximum adsorption capacity of Jackfruit leaf powder on methylene blue is 326.32 mg/g [1]. It has been the maximum uptake capacity of Congo red dye by Aloe vera leaves shell was 1850 mg/g [11]. Decolorization of Novacron blue has been studied by electrochemical degradation [26], TiO$_2$/palygorskite nanocomposite photocatalyst [27], *Bacillus badius,* and *Bacillus sphaericus* bacteria [28]. The instrumental setup for the electrochemical degradation and synthesis of TiO$_2$/palygorskite nanocomposite is a cost-intensive method. On the other hand, there is a huge risk of propagation of bacteria in the laboratory which may cause epidemic diseases.

Polyaniline emeraldine salt was synthesized by polymerization technique in presence of an oxidizing agent ammonium persulphate. The synthesized salt was used as an adsorbent to remove Novacron Blue ECR from the aqueous solution. About 88% of Novacron blue ECR dye was removed at optimized conditions after 80 minutes of contact time [29]. The removal efficiency of Novacron blue 4R by the adsorption on the surface of activated carbon was studied both theoretically and experimentally. The removal efficiency was found 96.24% and 93.63%, respectively at optimized conditions [30].

Removal of dye from wastewater by adsorption technique especially with the bio-adsorbent is a cost-effective and less hazardous method in comparison to the others. Novacron blue is an azo dye having high water solubility, which is used abundantly in different textile industries of Bangladesh. The availability of jackfruit as well as jackfruit seeds in Bangladesh is very high and can be collected at a cheap rate. That is why, in the present study, the jackfruit seed powder (JSP) was used as an adsorbent to decolorize the textile dye Novacron blue. The decolorization efficacy was monitored by a UV-Visible spectrophotometer. The adsorption of Novacron blue was investigated at various physico-chemical parameters such as different amounts of adsorbent, initial dye concentration, initial pH, initial temperature, and contact time. The Phytotoxic effect was also studied under Novacron blue solution and decolorized solution.

2   Materials and Methods

2.1   Chemicals, Reagents, and Instruments

Jackfruit seeds were collected from the local area of Barishal, Bangladesh. A textile dye Novacron blue was collected from a textile industry of Gazipur, Bangladesh. Deionized water was used as a reference in a UV-visible spectrophotometer. Ethanol and acetone were used to clean the glass apparatus used in the present study. All reagents and solvents were purchased from Merck, Germany, and used for the study without further purification. Adsorption was carried out in an orbital shaker (Model No-JSOS-300) and the decolorization was monitored by a UV-Visible spectrophotometer (Lamda-365) at 200 - 800 nm.

2.2   Preparation of Adsorbent
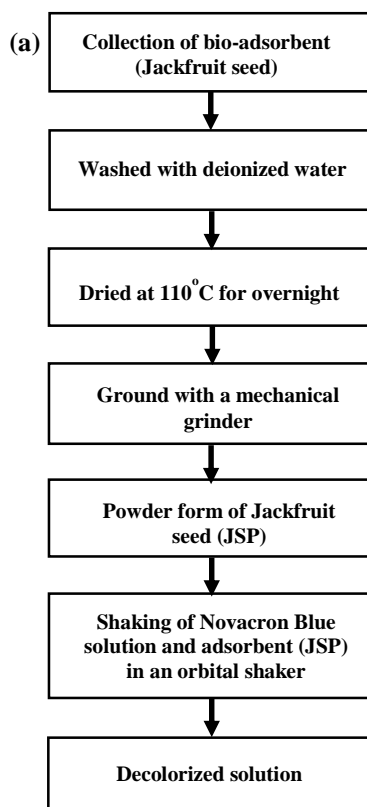
Jackfruit seeds were washed with distilled water to remove the surface adhered particles and water-soluble materials. Then washed jackfruit seeds were heated in an oven at 110ºC overnight. The dried seeds were ground with a grinder to make powder. The ground powders were sieved manually.

2.3   Preparation of Dye Solutions

500 ppm of an aqueous solution of Novacron blue was prepared in 500 mL of volumetric flask and kept as a stock solution. Solutions of different concentrations were prepared from stock solution by appropriate dilution.

2.4   Decolorization Study

A definite amount of JSP was added to a solution of Novacron blue and shaken with an orbital shaker at 210 rpm of agitation rate. About 2-3 mL solution was collected after a definite time interval and centrifuged at 200 rpm for 10 minutes. The baseline correction of the UV-Visible spectrophotometer was carried out by using deionized water which was used as a reference. After that absorption of the clear dye solution was measured at λ_{max} = 602 nm wavelength by UV-Visible spectrophotometer. A schematic representation for the whole process is shown in Fig. 1.

Percentage of decolorization of Novacron blue by JSP was determined by the following equation:

$$\text{Decolorization (\%)} = \frac{A_0 - A_t}{A_0} \times 100$$

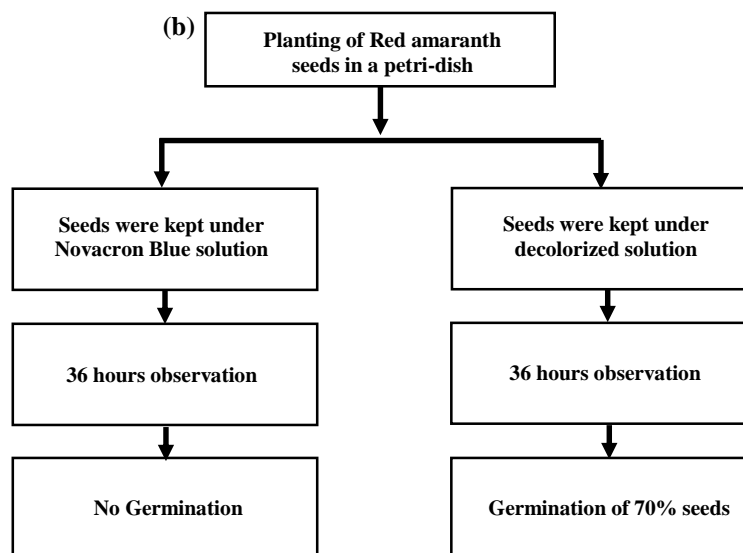where, A_o and A_t are initial and final absorbance of Novacron blue solution, respectively.

Fig. 1 A schematic representation for the (a) decolorization and (b) phytotoxic study of Novacron blue dye by JSP.

2.5 Decolorization Study of Novacron Blue by Various Physicochemical Parameters

2.5.1 Decolorization by JSP

Decolorization was studied with various adsorbent doses (0.5 g - 12.0 g of JSP) at a fixed concentration (100 ppm), different dye concentrations (50 - 250 ppm) with a fixed amount of JSP (10 g). The effect of temperature (25ºC - 60ºC) and pH (4.3 - 8.4) on decolorization was also investigated. The volume of Novacron blue solution was kept at 100 mL to carry out all the experiments. The decolorization of 100 mL of Novacron blue (100 ppm) by JSP (10 g) was also investigated at different time intervals up to 2.5 hours. Effects of all the physicochemical parameters on decolorization were monitored with the UV-visible spectrophotometer.

2.5.2 Phytotoxic Study by Germination Process

Phytotoxicity of decolorized dye solution and initial dye solution was tested by using a few seeds of Red Amaranth (*Amaranthus cruentus*). These three solutions with 10 seeds of Red Amaranth were taken in two Petri dishes separately for 36 hours. After 36 hours percent of germination was observed in each solution by using the following equations [31]-[32]:

$$\text{Germination (\%)} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds set for test}} \times 100$$

3 Results and Discussion

3.1 Effect of Amount of Adsorbent

The decolorization of Novacron blue was increased with the increasing amount of JSP and reaches a constant level after a certain amount. The degree of decolorization of dye increased from 2% to 68% as the amount of JSP increased from 0.5 to 10.0 g and then remain constant (Fig. 2). With the increase of adsorbent dosage, the surface area of the adsorbent increases, which also increases the number of available sites for adsorption. In addition, the decolorization remains constant after 10.0 g of JSP is due to the saturation of adsorption sites [33]-[34].
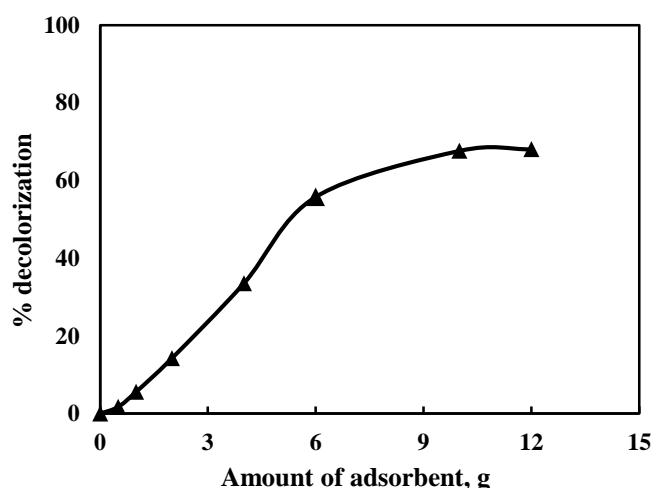
Fig. 2 Percentage of decolorization of Novacron blue at different amount of adsorbents.

3.2 Effect of Initial Concentration of Novacron Blue

It was observed that decolorization of Novacron blue by JSP was decreased from 67% to 51% with the increase in the initial concentration of dye from 50 to 250 ppm (Fig. 3). At a lower concentration, molecules have available binding sites on JSP, which results in better adsorption or decolorization of dye. The number of adsorbate molecules increases at high concentrations but the number of sites on the surface of the adsorbent is fixed. As a result, the number of available binding sites on JSP for the adsorbate molecule becomes limited at higher concentrations and the adsorption rate is found to be decreased [34]-[35].
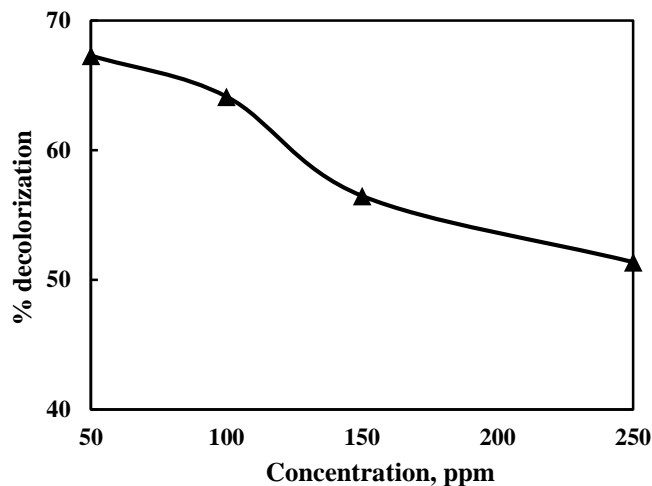
Fig. 3 Effect of initial concentration of Novacron blue on the decolorization.

3.3 Effect of pH

The percentage of decolorization was increased with the increase of pH from 4.3 to 8.4. The efficiency was increased from 66% to 68% after 30 minutes of contact time. In the acidic media, there is a competition between the cation of dye and the excess H^+ ion present in the solution to adsorb on the surface sites. As a result, the amount of adsorption on the surface of adsorbents is lower. On the contrary, the number of negatively charged sites is higher than the number of positively charged sites at the basic medium. So, there is an electrostatic attraction between the negatively charged sites and the dye cation which increases the amount of adsorption [36] (Fig. 4).
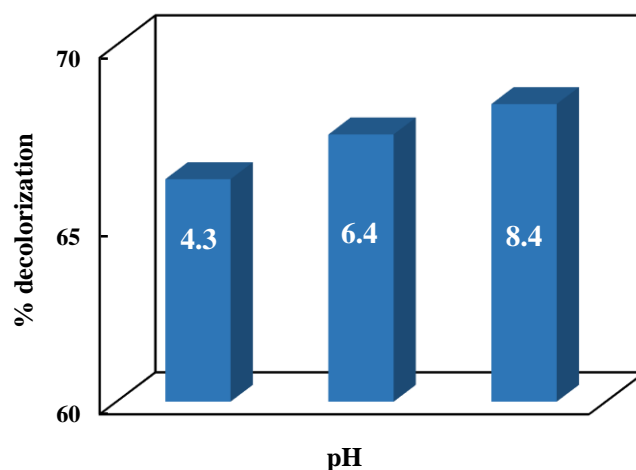
Fig. 4 Effect of pH on the decolorization of Novacron blue by the adsorbents.

3.4 Effect of Temperature

It was observed that decolorization of Novacron blue was decreased by JSP with the increase of temperature (Fig. 5) which

indicates the exothermic nature of the adsorption. The percentage of decolorization was decreased from 67% to 59% after 30 minutes of contact time with the increase of temperature from 25°C to 60°C. The decrease in decolorization with temperature may be occurred due to the decreased active sites of the adsorbent at high temperatures [37]-[38].
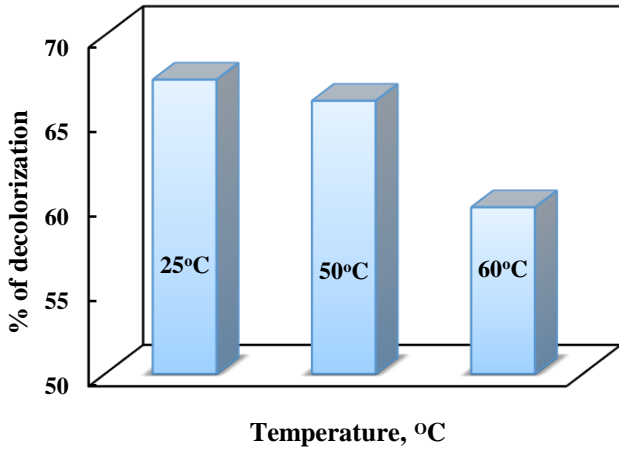

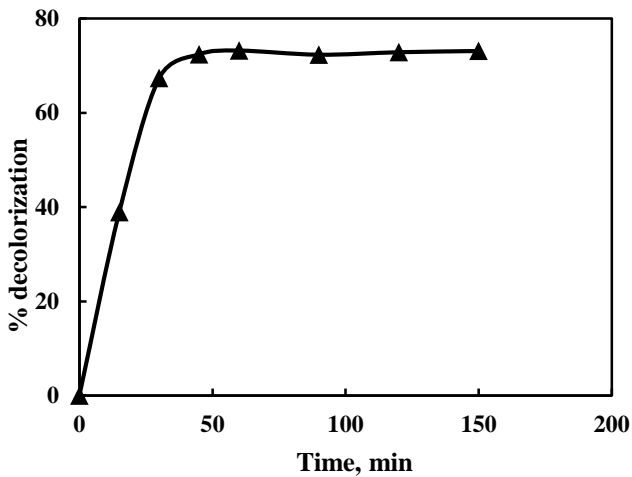Fig. 5 Percentage of decolorization of Novacron blue by JSP at different temperatures.

Fig. 6 Percentage of decolorization of Novacron blue at different contact times.

3.5 Effect of Contact Time

There is a rapid increase in the percentage of decolorization of Novacron blue with the increase of contact time as seen in Fig. 6. The percentage of decolorization became almost constant/slightly decreased after the adsorption of 60 minutes. The quick decolorization might be attributed to a large number of surface sites of adsorbent for adsorption at the initial stages but after a certain period of time, all the surface sites of the adsorbent become saturated [37],[39]. The surface sites of JSP for adsorption could be fully occupied after 60 minutes. At this stage, an equilibrium is established between the adsorbate and adsorbent. After that, desorption may take place [40].

3.6 Kinetic studies

The mechanism and kinetics of adsorption of Novacron blue on the surface of JSP can be obtained by fitting the experimental data to some kinetic models (pseudo-first-order, pseudo-second-order). The kinetic equations for the pseudo-first and pseudo-second-order models are as follows [41]-[42].
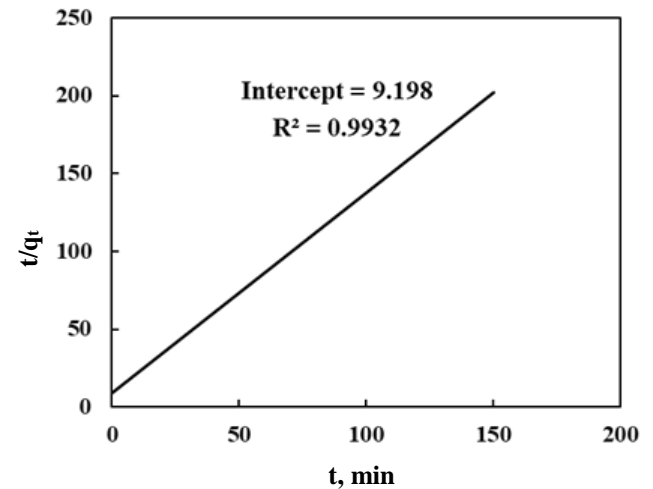
$$\log(q_e - q_t) = \log q_e - k_1 t \tag{1}$$

$$t/q_t = 1/(k_2 q_e^2) + t/q_e \tag{2}$$

where q_e and q_t are the amount of adsorbate adsorbed on adsorbent (mg/g) at equilibrium and any time t respectively. k_1 and k_2 are the corresponding rate constants for the pseudo-first and second-order reactions.
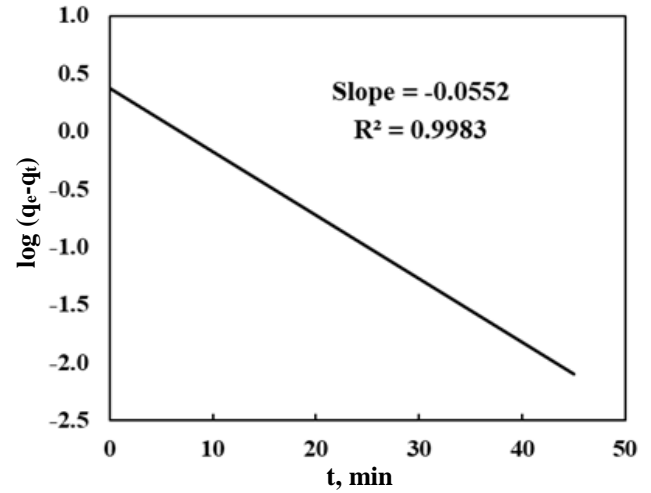
(a)

(b)

Fig. 7 (a) Pseudo-first order and (b) Pseudo-second order kinetic model for the adsorption of Novacron blue on JSP respectively.

The value of q_e and q_t are calculated by using the following equations [43]

$$q_t = (C_0 - C_t) V/W \tag{3}$$

$$q_e = (C_0 - C_e) V/W \tag{4}$$

where, C_0, C_t, and C_e represent the initial concentration, concentration at any time t, and equilibrium concentration of dye in mg/L respectively. V is the volume of the solution (L) used for adsorption and W is the mass of dry adsorbent (g).

All the kinetic parameters are evaluated separately from the plot of log (q_e-q_t) vs. log q_e and t/q_t vs. t (Fig. 7). The value of rate constants, maximum adsorption capacity, and correlation coefficient (R^2) are listed in Table 1. The value of R^2 suggests that the adsorption on JSP follows pseudo-first-order kinetics.

Table 1 Kinetic parameters for the pseudo-first and pseudo-second order models.

JSP				
q_e	Pseudo-first-order		Pseudo-second-order	
mg/g	k_1	R^2	k_2	R^2
0.732	0.0552	0.9983	0.2029	0.9932

3.7 Phytotoxicity by Germination

Phytotoxic effect on Red Amaranth (*Amaranthus cruentus)* by Novacron blue and decolorized dye solutions have been explored in Fig. 8 and Table 2. A significant phytotoxic effect on Red Amaranth (*Amaranthus cruentus*) by the decolorized dye solution of Novacron blue was observed, which reveals the efficiency of JSP as a bio-adsorbent.

Table 2 Germination of Red Amaranth seeds at different conditions.

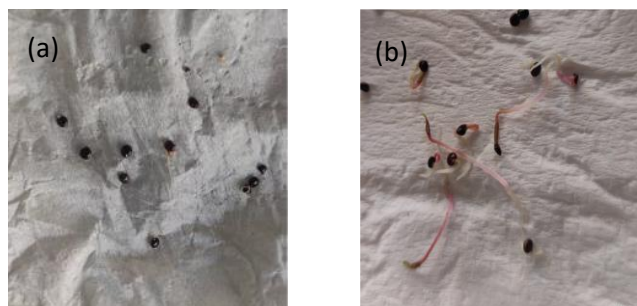| Germination condition	% of seeds germinated
Novacron blue solution	0%
Decolorized Novacron blue by JSP	70%

Fig. 8 Phytotoxic effect of (a) Novacron blue solution and (b) decolorized solution of Novacron blue.

4 Conclusion

Jackfruit seeds showed good decolorization efficiency to Novacron blue through the adsorption process. The adsorption efficiency of JSP was transformed with the change of various physicochemical parameters. The maximum adsorption capacity of JSP in removing the Novacron blue dye from wastewater is better than some other previously reported research. The adsorption on JSP is found to follow pseudo-first-order kinetics. The phytotoxic effect of dye solution is significantly changed after decolorization. The percentage of adsorption was better at basic medium and low temperatures. The unconcerned dumping of agricultural wastage to the environment may cause a severe problem which can be reduced by their use as an adsorbent in removing contaminants from wastewater. Bangladesh is one of the world's biggest garment manufacturing countries and that is why wastewater is commonly dumped directly into rivers and streams without any treatment. The main reason behind this problem is the existing expensive methods for wastewater treatment. A low-cost adsorbent and inexpensive industrial setup may be a fruitful solution to this problem. It is expected that the above findings in the present research will make the JSP a potential candidate to use as an adsorbent in removing pollutants from wastewater.

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