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

Rafi Ahmed Miah\textsuperscript{1}, Mohammad Jahangir Alam\textsuperscript{1}, Aklima Khatun\textsuperscript{2}, Mahmudul Hassan Suhag\textsuperscript{1,2} and Md. Nazmul Kayes\textsuperscript{1*}

\textsuperscript{1}Department of Chemistry, University of Barishal, Barishal-8254, Bangladesh
\textsuperscript{2}Department of Chemistry for Materials, Mie University, Mie 514-8507, Japan

Received: January 17, 2022, Revised: March 13, 2022, Accepted: March 13, 2022, Available Online: March 15, 2022

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, Phytoxic Efficiency.

This work is licensed under a Creative Commons Attribution-Non Commercial 4.0 International License.

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\times10^6 tones and about 10,000 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 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 Panica 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 electrodechemical degradation [26], TiO\textsubscript{2}/palygorskite nanocomposite photocatalyst [27], Bacillus bacteria [28]. The instrumental setup for the electrochemical degradation and synthesis of TiO\textsubscript{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 110°C 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 $\lambda_{\text{max}} = 602$ 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, $A_0$ 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 (25°C - 60°C) 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].

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].

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).

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].

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].

\[
\log(q_e - q_t) = \log q_e - k_1 t
\]  

\[
t/q_t = 1/(k_2 q_e^2) + t/q_e
\]

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.

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.

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]

\[
q_t = (C_0 - C_t) V/W
\]

\[
q_e = (C_0 - C_e) V/W
\]

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 $\log (q_e-q)$ vs. log $q_e$ and $t/q$ 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          | mg/g | Pseudo-first-order | Pseudo-second-order |
|--------------|------|--------------------|---------------------|
|              |      | $k_1$              | $R^2$               |
|              |      |                    |                     |
|              | 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 physiochemical 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.

Acknowledgment

We would like to thank the University of Barishal as well as the University Grant Commission (UGC), Bangladesh for the financial support.

References

[1] Uddin, M., Rukanuzzaman, M., Khan, M., Rahman, M. and Islam, M., 2009. Jackfruit (Artocarpus heterophyllus) leaf powder: An effective adsorbent for removal of methylene blue from aqueous solutions. *Indian Journal of Chemical Technology*, 16, pp. 142–149.

[2] Shah, J., Rasul Jan, M., Haq, A. and Khan, Y., 2013. Removal of Rhodamine B from aqueous solutions and wastewater by walnut shells: kinetics, equilibrium and thermodynamics studies. *Frontiers of Chemical Science and Engineering*, 7(4), pp.428–436.

[3] Joseph, N.T., Chinonye, O.E., Philomena, I.K., Christian, A.C. and Elijah, O.C., 2016. Isotherm and kinetic modeling of adsorption of dyestuffs onto kola nut (Cola acuminata) shell activated carbon. *Journal of Chemical Technology and Metallurgy*, 51(2), pp. 188-201.

[4] Yagub, M.T., Sen, T.K., Afroze, S. and Ang, H.M., 2014. Dye and its removal from aqueous solution by adsorption:a review. *Advances in Colloid and Interface Science*, 209, pp.172-184.

[5] Mittal, A., Mittal, J., Malviya, A., Kaur, D. and Gupta, V.K., 2010. Decoloration treatment of a hazardous triarylmethane dye, Light Green SF (Yellowish) by waste material adsorbs. *Journal of Colloid and Interface Science*, 342(2), pp.518-527.

[6] Saratale, R.G., Saratale, G.D., Chang, J.S. and Govindwar, S.P., 2011. Bacterial decolorization and degradation of azo dyes: A review. *Journal of the Taiwan Institute of Chemical Engineers*, 42(1), pp. 138-157.

[7] Murugan, T., Ganapathi, A. and Valliappan, R., 2010. Removal of dyes from aqueous solution by adsorption on biomass of mango (Mangifera indica) leaves. *E-Journal of Chemistry*, 7(3), pp. 669-676.

[8] Thakur, A. and Kaur, H., 2017. Response surface optimization of Rhodamine B dye removal using paper industry waste as adsorbent. *International Journal of Industrial Chemistry*, 8, pp. 175-186.

[9] Kumar, B. and Kumar, U., 2014. Removal of Malachite Green and Crystal Violet Dyes from Aqueous Solution with Bio-Materials: A Review. *Global Journal of Researches in Engineering*, 14(4), pp. 50-60.

[10] Mohammed, M.A., Shitu, A. and Ibrahim, A., 2014. Removal of Methylene Blue Using Low Cost Adsorbent: A Review. *Research Journal of Chemical Sciences*, 4, pp. 91-102.

[11] Khiamiabadi, Y.O., Mohammadi, M.J., Shegerd, M., Sadeghi, S., Saeedi, S. and Basiri, H., 2017. Removal of Congo red dye from aqueous solutions by a low-cost adsorbent: activated carbon prepared from Aloe vera leaves shell. *Environmental Health Engineering Management Journal*, 4, pp. 29-35.

[12] Daouda, A., Honorine, A.T., Bertrand, N.G., Richard, D. and Domga, 2019. Adsorption of Rhodamine B onto Orange Peel Powder. *American Journal of Chemistry*, 9(5), pp. 142-149.

[13] Thakur, A. and Kaur, H., 2016. Removal of hazardous Rhodamine B dye by using chemically activated low cost
adsorbent: Pine cone charcoal. International Journal of Chemical and Physical Sciences, 5(4), pp. 17-28.

[14] Hameed, B.H. and El-Khaiary, M.I., 2008. Malachite green adsorption by rattan sawdust: Isotherm, kinetic and mechanism modeling. Journal of Hazardous Materials, 159, pp. 574-579.

[15] Banat, F., Al-Asheh, S. and Al-Makhdumeh, L., 2003. Evaluation of the use of raw and activated date pits as potential adsorbents for dye containing waters. Process Biochemistry, 39, pp. 193-202.

[16] Gong, R., Li, M., Yang, C., Sun, Y. and Chen, J., 2005. Removal of cationic dyes from aqueous solution by adsorption on peanut hull. Journal of Hazardous Materials, 121, pp. 247-250.

[17] Bhattacharya, K.G. and Sharma, A., 2005. Kinetics and thermodynamics of Methylene Blue adsorption on Neem (Azadirachta indica) leaf powder. Dyes and Pigments, 65, pp. 51-59.

[18] Vadivelan, V. and Vasanth Kumar, K., 2005. Equilibrium, kinetics, mechanism, and process design for the sorption of methylene blue onto rice husk. Journal of Colloid and Interface Science, 286, pp. 90-100.

[19] Nassar, M.M., Hamoda, M.F. and Radwan, G.H., 1995. Adsorption equilibria of basic dyestuff onto palm-fruit bunch particles. Water Science and Technology, 32, pp. 27-32.

[20] Ponnusamy, S.K. and Subramaniam, R., 2013. Process optimization studies of Congo red dye adsorption onto cashew nut shell using response surface methodology. International Journal of Industrial Chemistry, 4(1), pp.1-10.

[21] Garg, V.K., Gupta, R., Yadav, A.B. and Kumar, R., 2003. Dye removal from aqueous solution by adsorption on treated sawdust. Bioresource Technology, 89(2), pp. 121-124.

[22] Robinson, T., Chandran, B. and Nigam, P., 2002. Removal of dyes from a synthetic textile dye effluent by biosorption on apple pomace and wheat straw. Water Research, 36, pp. 2824-2830.

[23] Namasiyayam, C., Radhika, R. and Suba, S., 2001. Uptake of dyes by a promising locally available agricultural solid waste: Coir pith. Waste Management, 21, pp. 381-387.

[24] Uddin, M.K. and Nasar, A., 2020. Decolorization of Basic Dyes Solution by Utilizing Fruit Seed Powder. KSCE Journal of Civil Engineering, 24, pp. 345-355.

[25] Kooh, M.R.R., Dahri, M.K. and Lim, L.B.L., 2016. Jackfruit seed as a sustainable adsorbent for the removal of Rhodamine B dye. Journal of Environment and Biotechnology Research, 4, pp. 7-16.

[26] Rocha, J.H.B., Solano, A.M.S., Fernandes, N.S., da Silva, D.R., Peralta-Hernandez, J.M. and Martinez-Huitle, C.A., 2012. Electrochemical Degradation of Remazol Red BR and Novacron Blue C-D Dyes Using Diamond Electrode. Electrocatalysis, 3, pp. 1-12.

[27] Assis, M.L.M. de, Junior, E.D., Almeida, J.M.F. de, Silva, I. do N., Barbosa, R.V., Santos, L.M. dos, Dias, E.F., Fernandes, E.S. and Martinez-huitle, C.A., 2021. Photocatalytic degradation of Novacron blue and Novacron yellow textile dyes by the TiO2/palgyorskite nanocomposite. Environmental Science and Pollution Research, 28, pp. 64440-64460.

[28] Mahhub, K.R., Morium, B., Ahmed, M.M., Akond, M.A. and Andrews, S., 2015. Decolorization of Novacron Blue and Novacron Super Black Azo Dyes by Bacillus spp Isolated from Textile Effluents in Bangladesh. Journal of Scientific Research, 7, pp. 45-53.

[29] Lingeswari, U.D., Vimala, T., 2019. Kinetics and isotherm study of adsorption of industrial dyes Novacron Blue ECR and Reactive Yellow 145 by PANI-Emeraldine salt. International Journal of Research and Analytical Reviews, 6, pp. 698-705.

[30] Barrak, N., Mannai, R., Zaidi, M., Achour, S., Kechida, M., Helal, A.N., 2018. Optimization of Novacron Blue 4R (NB4R) removal by adsorption process on activated carbon using response surface methodology. Desalination and Water Treatment, 104, pp. 346-353.

[31] Vihbuti, Shahi, C., Bargali, K. and Bargali, S.S., 2015. Seed germination and seedling growth parameters of rice (Oryza sativa) varieties as affected by salt and water stress. Indian Journal of Agricultural Sciences, 85, pp. 102-108.

[32] Rahman, A., Rahman, S., Mohiuddin, K.M., Chowdhury, A.H. and Chowdhury, A.K., 2019. Germination and seedling growth of rice (Oryza sativa L.) as affected by varying concentrations of loom-dye effluent. Journal of the Bangladesh Agricultural University, 17, pp. 153-160.

[33] Badii, K., Ardejani, F.D., Saberi, M.A., Limeae, N.Y. and Shafaei, S.Z., 2010. Adsorption of Acid blue 25 dye on diatomite in aqueous solutions. Indian Journal of Chemical Technology, 17, pp. 7-16.

[34] Satish, P., Renukdas, S. and Patel, N., 2011. Removal of Methylene Blue, a Basic Dye from Aqueous Solutions by Adsorption Using Teak Tree (Tectona Grandis) Bark Powder. International Journal of Environmental Sciences, 1(5), pp. 711-726.

[35] El Qada, E., 2020. Kinetic Behavior of the Adsorption of Malachite Green Using Jordanian Diatomite as Adsorbent. Jordanian Journal of Engineering and Chemical Industries, 3(1), pp. 1-10.

[36] Batzias, F.A. and Sidiras, D.K., 2007. Simulation of dye adsorption by beech sawdust as affected by pH. Journal of Hazardous Materials, 141, pp. 668-679.

[37] Khan, T.A., Sharma, S. and Ali, I., 2011. Adsorption of Rhodamine B dye from aqueous solution onto acid activated mango (Magnifera indica) leaf powder: Equilibrium, kinetic and thermodynamic studies. Journal of Toxicology and Environmental Health Sciences, 3, pp. 286-297.

[38] Omar, H., El-Gendi, A. and Al-Ahmary, K., 2018. Bioremoval of toxic dye by using different marine macroalgae. Turkish Journal of Botany, 42, pp. 15-27.

[39] Umpuch, C., 2015. Removal of yellow 20 dye from aqueous solution using organo-rice straw: Characteristic, kinetic and equilibrium studies. Engineering Journal, 19(2), pp. 59-69.

[40] Kayes, M.N., Chowdhury, M.M.R., Seikh, M.A., Suhag, M.H. and Akter, F., 2019. Application of sugarcane bagasse as an adsorbent for treatment of a textile dye Rhodamine B. Barisal University Journal Part 1, 6, pp. 47-57.

[41] Tseng, R.L., Wu, F.C and Jiang, R.S., 2010. Characteristics and Applications of the Lagergren’s First-Order Equation for Adsorption Kinetics. Journal of the Taiwan Institute of Chemical Engineers, 41, pp. 661-669.

[42] Futianos K., Voudrias E. and Kokkalis E., 2000. Sorption Kinetics. Journal of the Taiwan Institute of Chemical Engineers, 31(5), pp. 431-438.

[43] Vidyasagar, V., 2011. Evaluation of the use of raw and activated date pits as potential adsorbents for dye containing waters. Process Biochemistry, 39, pp. 193-202.

[44] Gong, R., Li, M., Yang, C., Sun, Y. and Chen, J., 2005. Removal of cationic dyes from aqueous solution by adsorption on peanut hull. Journal of Hazardous Materials, 121, pp. 247-250.

[45] Bhattacharya, K.G. and Sharma, A., 2005. Kinetics and thermodynamics of Methylene Blue adsorption on Neem (Azadirachta indica) leaf powder. Dyes and Pigments, 65, pp. 51-59.