



Removal of Fe³⁺ Ions from Wastewater by Activated *Borassus flabellifer* Male Flower Charcoal

Goutam Kumar, Nusrat Tazeen Tonu*, Palash Kumar Dhar and Md. Mahiuddin

Chemistry Discipline, Khulna University, Khulna, Bangladesh

Received: 13 March 2021, Revised: 12 June 2021, Accepted: 01 July 2021

© University of Tehran

ABSTRACT

Safe and clean water is essential for all living beings. Consumption of polluted water which is contaminated with iron may cause serious health implications. Therefore, removal of Fe³⁺ from wastewater is prerequisite for further uses. The present study intended to prepare activated charcoal (AC) from *Borassus flabellifer* male flower (BF) for the removal of Fe³⁺ ions from wastewater in a cost effective way. BFAC was produced based on carbonization method. Surface morphology and elemental composition were investigated by Scanning Electron Microscopy and Energy Dispersive X-Ray Spectroscopy. Additionally surface charge was determined by iodine number and zero point charge calculation. Batch adsorption studies were monitored using UV-visible spectroscopy. The obtain results showed a maximum adsorption at pH 8 with 0.3g adsorbent dosage at 50ppm initial Fe³⁺ ion concentration for 130 min contact time. The analysis of adsorption isotherm was in good agreement with both Langmuir and Freundlich adsorption isotherms. The Fe³⁺ removal method was found to be controlled by 1st order kinetics mechanism. However, the production cost was much cheaper and the removal performance was comparatively better than other commercial charcoals. Hence, BFAC could be used as a commercial charcoal in rural area of Bangladesh for purification of waste water.

KEYWORDS: *Borassus flabellifer* male flower, activated charcoal, UV-visible spectroscopy, Adsorption isotherms.

INTRODUCTION

Water is the most important substance for all living beings. But unfortunately, water sources are being contaminated by various pollutants such as heavy metals, pesticides, and toxins from diverse factors like oil pollution, atmospheric deposition, industrial waste disposal, etc (Biswas et al., 2013; Dhanik et al., 2017). Now-a-days, presence of heavy metals in groundwater has become foremost public concern due to their toxicity, long-term persistence, bioaccumulation in the food chain. Being non-biodegradable in nature, they possess a great threat to human as well as to all living organisms in aquatic ecosystem (Igwe et al., 2003; Gil et al., 2007). However, various activities like rapid industrialization, urbanization, transportation, etc. are responsible for increasing the concentration of heavy metals on earth crust (Ara et al., 2018).

Since Fe ions are found in many industries, like- car, coatings, steel and aeronautic industries, having great attention in research field (Chaturvedi et al., 2012; Öztaş et al., 2008). Iron can raise the color, salinity and turbidity of water as well as cause bad taste (Zhang et al., 2020). Living organisms need Fe for proper passage and storage of oxygen but excessive

* Corresponding Author, Email: nusrattazeen@ku.ac.bd

intake of Fe leads to life threatening Diseases- heart failure, poor growth, hemochromatosis, siderosis, diabetes, etc. (Sarin et al., 2004). According to Environment Protection Agency (EPA), the maximum permissible limit of iron in drinking water is 0.3 mg/L (Zaini et al., 2010). But the concentration of iron in the north western part of Bangladesh is very high (16.3 mg/L) and regular iron consumption for a person is approximately 41.1 mg (Meril et al., 2012). So, the removal of iron from water is necessary.

A number of methods have been used by researchers to remove Fe from water, but most of them are of limited in use for their high operational cost and waste management process (Modin et al., 2011). But adsorption techniques have a great attention, because of their operation in easy management through a cost effective way (Baseri, 2012). A survey of literature suggests that natural resources; such as- *Xanthium pensylvanicum* (Salehzadeh, 2013), tea leaves (Chakrabarty et al., 2017., Mamun et al., 2019), orange peel (Mamun et al., 2019), *Bombax Costatum* calyx (Osemeahon et al., 2013), Cuscuta powder (Dhanik et al., 2017), Coconut Shell (Bernard et al., 2013), brown husk of ripe coconut (Livinus et al., 2018), Hebba Clay (Shama et al., 2010); artificially synthesized materials; such as- mixture of rice husk ash, palm oil fuel ash and coal fly ash (Dahlan et al., 2013), Natural apatite from phosphate rock (Qian et al., 2014), sewage sludge-Polyvinylidene fluoride polymer (Aziz et al., 2016), CuO Nanoparticles (Chakrabarty et al., 2021); activated carbon prepared from Cotton stem (Shama et al., 2010), Date Pits (Awwad et al., 2008), coconut shell (Rose et al., 2012), modified coconut shell (Beenakumari et al., 2009), oil palm shell (Allwar, 2016), local agro residue (Magda et al., 2013), Sugarcane Bagasse (Syed et al. 2020), epicarp of *Detarium microcarpum* and *Balanitea egyptiaca* shells (Wyasu et al., 2016); commercial activated carbon (Kouakou et al., 2013), etc. was explored for the removal of iron from waste water. To the best of our knowledge, *Borassus flabellifer* male flower has not been used yet.

Borassus flabellifer is very available tree in Bangladesh. It has male and female flowers on separate trees (Wang et al., 2009). Male flowers are used for the preparation of crude sugar (jiggery). But as flower stalks glow old it becomes hard like thin wood and have no use but waste (Shrestha et al., 2012; Rana et al., 2009). Till now BF has not been used for the purpose of the removal of metals from water and the production of charcoal by carbonization process is very easy and inexpensive, which could be a great opportunity for the poor people of Bangladesh for water purification. So, BFAC could be a novel adsorbent for the removal of iron from waste water. The aim of the present work is to prepare BFAC and to use it for the removal of Fe^{3+} ions from aqueous system. Using a batch adsorption study, different experimental parameters, isotherms and kinetic studies were done.

MATERIALS AND METHODS

BF male flower was collected from *Borassus flabellifer* male tree, those were randomly chosen from local place of Khulna, Bangladesh. The samples were washed with cold water and dried under sunlight until a constant weight obtained. About 2 kg of sample was taken for carbonization process (Ekpete et al. 2017). At the end of the process, charcoal was obtained, designated as BFAC, and used as raw material after crushing followed by hand milling in this study. The surface morphology of BFAC was investigated with the help of Scanning electron microscopy (SEM) measurements (JEOL JSM-6510A, JEOL Ltd., Tokyo, Japan) equipped with a JEOL JED 2300 Energy-dispersive X-ray (EDX) spectrometer.

To study the behavior of BFAC surface, zero point charge (pH_{ZPC}) was calculated by solid addition method (Ojha et al., 2015). pH (2-12) was determined by pH meter (pH5011, EZODO, Taiwan) and was maintained by the procedure outlined Chakrabarty et al. (2017).

To measure of activity level of BFAC the iodine number was calculated by the Eq. 1 (Syed et al. 2020). Where, I is iodine number in mg/g, C_{blank} and $C_{Na_2S_2O_3}$ is the consumption of volume of standard sodium thiosulphate for blank reading and after adsorption of BFAC respectively, W_I is molecular weight of iodine, S_I is molarity of iodine and W_{BFAC} is weight of BFAC.

$$I = (C_{blank} - C_{Na_2S_2O_3}) \times W_I \times S_I \times \frac{10}{W_{BFAC} \times C_{blank}} \quad (1)$$

To assess the adsorption capacity of BFAC, a series of batch adsorption study was carried out based on the prescribed method Sheibani, et al. (2012) using mechanical shaker (SK-O180-S, SCIOLOGEX, China) and UV absorption spectrometer (UVD-3200, Labomed, U.S.A.). The removal percentage (%R) and the amount of adsorbed $FeCl_3$ (W_e) in mg/g was calculated by Eq. 2 and Eq. 3, respectively. Where, C_i and C_f is the initial and final concentration of $FeCl_3$ in solution respectively, V is volume (L) of $FeCl_3$ solution and M is the mass (g) of dry BFAC.

$$\%R = \frac{C_i - C_f}{C_i} \times 100 \quad (2)$$

$$W_e = \frac{C_i - C_f}{M} \times V \quad (3)$$

To determine the adsorption nature of BFAC, Langmuir (Eq. 4), Freundlich (Eq. 5) and Temkin (Eq. 6) isotherms were adopted. Where, Q_m is Langmuir constant, b is adsorption energy, C_e is the equilibrium concentration of Fe^{3+} ions (mg/L), Q_e is the amount of metal adsorbed per unit weight of adsorbent (mg/g), K is a parameter related to the binding energy, n is a measure of a deviation for the adsorption system, T is the absolute temperature (K) and R is the universal gas constant, b_T is a constant related to the heat of adsorption, and a_T is the equilibrium binding constant for maximum binding energy (Sika et al., 2010; Akkaya et al., 2005).

$$\frac{C_e}{Q_e} = \frac{C_e}{Q_m} + \frac{1}{bQ_m} \quad (4)$$

$$\log Q_e = \log K + \frac{1}{n} \log C_e \quad (5)$$

$$q_e = B_T \log a_T + B_T \log C_e \quad (6)$$

Study of adsorption kinetics were done using pseudo first-order, Lagergren, (Eq. 7), pseudo second-order (Eq. 8) and Elovich model (Eq. 9). Where, q_e and q_t are the amounts of Fe^{3+} ion adsorbed (mg/g) at equilibrium and time t , respectively, k_1 and k_2 is the rate constant of the pseudo first-order and second-order adsorption operation respectively, α (g/kg.min) is the initial adsorption rate, β (kg/g) is the desorption constant (Tabak et al., 2009; Sika et al., 2010).

$$\log(q_e - q_t) = \log q_e - \frac{k_1 t}{2.303} \quad (7)$$

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{1}{q_e} t \quad (8)$$

$$q_t = \frac{1}{\beta} \ln(\alpha\beta) + \frac{1}{\beta} \ln t \quad (9)$$

RESULTS AND DISCUSSION

The surface morphology was characterized by SEM (Fig. 1) image. From the Fig. 1, it was seen that BFAC had irregular and porous surface. It had many pits and grooves of different sizes. The purity of BFAC was also checked by EDX spectroscopy (Fig. 2). Results showed that mostly carbon (95.16%) was present, responsible for greater degree of adsorption. A small quantity of oxygen (4.83%) was present with other impurities, have minor or literally no effect on adsorption efficiency. Similar experiments were carried out for sugarcane bagasse charcoal (Syed et al., 2020), having irregular and porous surface and contained mostly carbon with a little percentages of oxygen

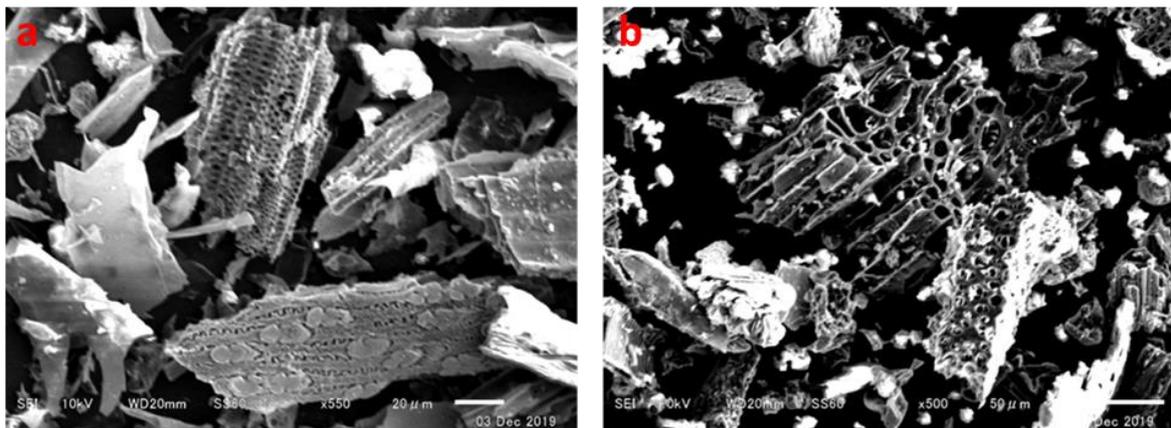


Fig. 1. SEM images of BFAC; scaling (a) 20 μm, (b) 50 μm

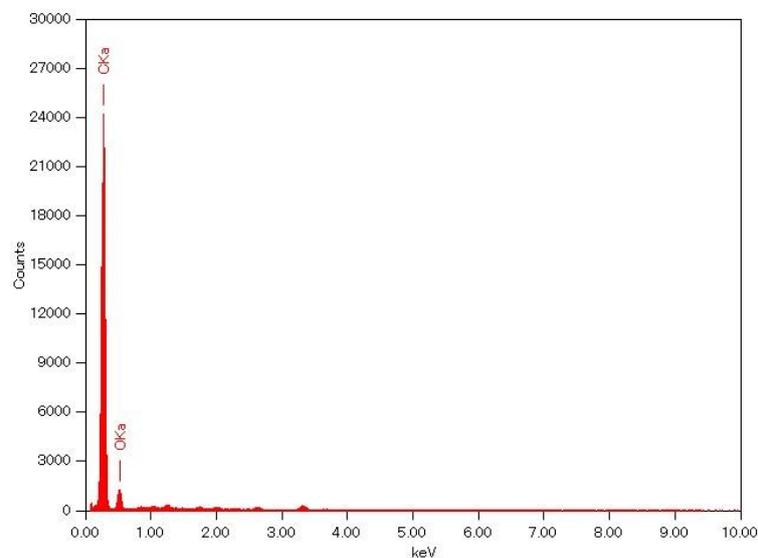


Fig. 2. EDX image of BFAC

In order to test the activity level of BFAC, the iodine value was determined. The BFAC sample with iodine value 691.88 mg/g showed an appreciable degree of activation (Ghaedi et al., 2012). Similar observation has been previously reported for sugarcane bagasse where the iodine value was 611.768 mg/g (Syed et al., 2020).

To determine pH_{ZPC} for the surface of BFAC, a graph of ΔpH vs pH_i were analyzed (Figure 3). The point at which ΔpH and pH_i intersect each other was recorded as pH_{ZPC} and was determined on the pH_i axis. The pH_{ZPC} value of BFAC was found to be 7.5 for the concentration of 0.1 M NaCl. It means that at values $\text{pH} > 7.5$ the surface area of the BFAC was negatively charged (Iman et al., 2013). Syed et al., 2020, investigated the pH_{ZPC} value was 7.3 for sugarcane bagasse charcoal and confirmed the surface was negatively charged.

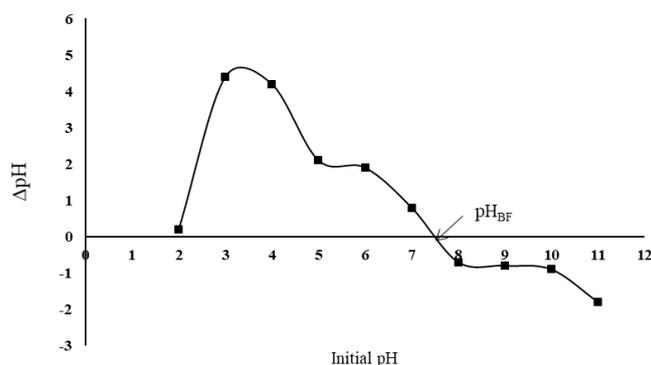


Fig. 3. Determination of zero point charge (pH_{ZPC}) of BFAC

To study the effect of pH, the pH of the solution was varied from 2 to 11 (Concentration = 50 ppm, contact time = 30 minutes, dose = 0.2 g). A graph (Figure 4) of pH of the solution versus removal percentage of Fe^{3+} ion were investigated. The maximum removal was 81.24% at pH 8 and after that the removal efficiency was gradually decreased with increase of pH. In the solution, other than hydrogen and hydroxyl ion, there was Fe^{3+} ion which is positively charged. The surface was negatively charged, as confirmed from the value of pH_{ZPC} , responsible for suitable condition for positive ion adsorption. At the time of the pH preparation, as the pH increased the solution precipitated, making $\text{Fe}(\text{OH})_3$ in the solution, established the lower adsorption at higher pH (Syed et al. 2020). So, pH 8 was recorded as optimum pH for maximum removal of Fe^{3+} ion in aqueous solution. Similar study for the removal of Fe^{2+} ion from aqueous system was performed by Chakrabarty, et al., 2017, with waste tea leaves as adsorbent, found the optimum pH 8.0.

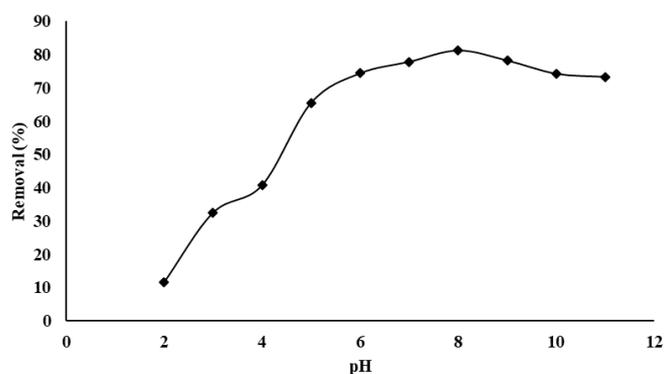


Fig. 4. Effect of pH for the removal of Fe^{3+} ions by using BFAC

To assess the effect of adsorbent dosage, the dosage of BFAC was gradually increased from 0.1g to 0.6g (pH = 8, contact time = 30 minutes, concentration 50 ppm). From figure 5, it was seen that the removal efficiency was increased 67% to 86% till the dosage was increased to 0.3g, this is due to the fact that with the increasing of dosage, the surface area also increases as well as active binding sites. But, further increase of dosage from 0.3g to 0.6g, decreases the removal percentage, could be the reason for coagulation of adsorbents being excess amount in the solution or having inactive binding sites. So, the optimum adsorption dose 0.3g. Similar result has been found for the removal of Fe^{3+} ions in aqueous system by waste tea leaf and orange peel (Mamun et al. 2019).

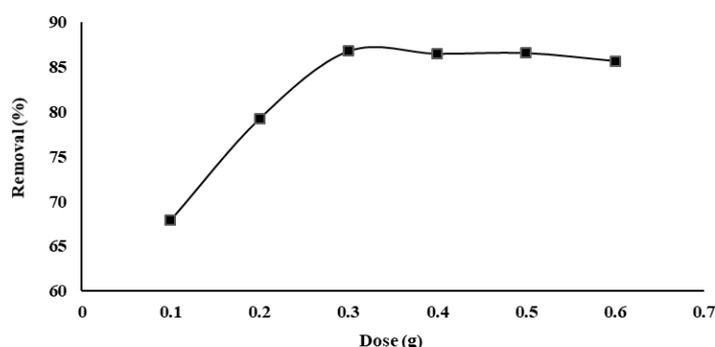


Fig. 5. Effect of dosage of BFAC for the removal of Fe^{3+} ion

In order to investigate the effect of initial Fe^{3+} ion concentration, the concentration of Fe^{3+} ion was increased from 10 to 100 ppm (pH = 8, contact time = 30 minutes, dose = 0.2 g). Figure 6 indicated that the removal percentage was increased from 10 ppm to 50 ppm. This is due to the reason that with the increasing of adsorbate dosage, the adsorption increases. The increase in adsorption is because of the resistance to mass transfer between adsorbate and adsorbent is stunned by concentration gradient which perform like a driving force. But after increasing the concentration from 50 ppm to 100 ppm, the adsorption gradually, could be the reason for solute to solute interaction and coagulation of adsorbate particles in the solution. So, the optimum Fe^{3+} ion concentration is 50 ppm. For sugarcane bagasse's, the highest percentage of Fe^{3+} ion removal was 78% for 90 ppm (Syed e al., 2020).

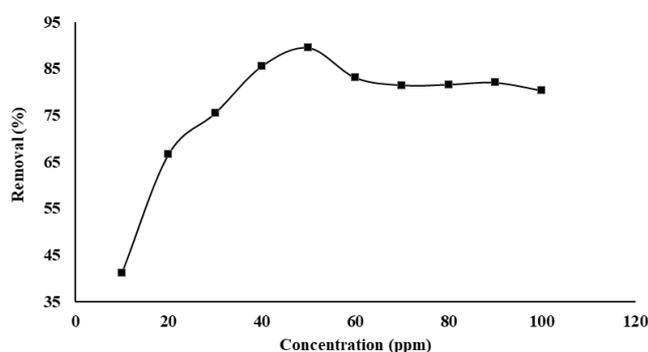


Fig. 6. Effect of initial concentration of Fe^{3+} ion for the removal of Fe^{3+} ion by using BFAC

To examine the effect of milling time BFAC was grinded by hand mortar and pastel and removal percentage was monitored with constant amount of adsorbent dosage (pH = 8, contact time = 30 minutes, dose = 0.2 g, concentration = 50 ppm). From Fig. 7, it was seen

that with the increasing of grinding time from 0h to 4h, the removal percentage increases from 80.24% to 92.89%. This is because with the increasing of milling time the particles were crushed resulting the increases of active surface area (Syed e al., 2020).

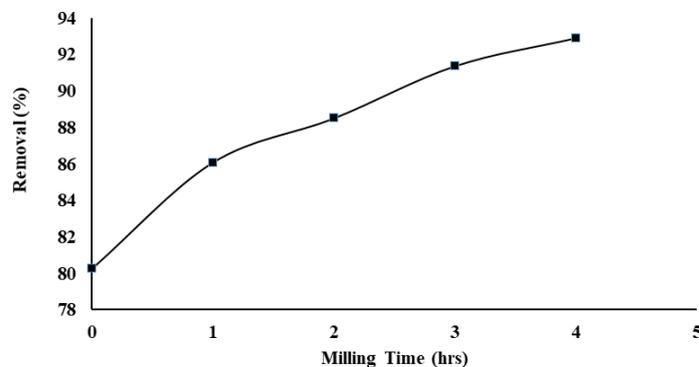


Fig. 7. Effect of milling time of BFAC for the removal of Fe³⁺ ion

To explore the effect of contact time, 50, 100, 150, 200, 250 and 300 ppm solutions were prepared. For each solution (pH = 8), 0.3g of BFAC was taken and shaken for 10 minutes. Then the amount of Fe³⁺ ion in mg/g was calculated. Again the solution was shaken for 10 minutes more and the amount of Fe³⁺ ion in mg/g was calculated. This process was continued till the saturation point was reached. A graph (Figure 8) of contact time in minutes versus the removal percentage of Fe³⁺ ion was investigated. The saturation point in minutes and the amount of Fe³⁺ ion removed in mg/g were calculated with respect to specific initial concentration of Fe³⁺ ion in solution. The results showed that with the increasing of contact time the removal efficiency increased. This was because of elongated interaction between the surface of the adsorbent and also the metals ions (Lo et al., 2012). From the Figure 9, it was noticed that the metal capacity of Fe³⁺ approached equilibrium for 50,100,150,200,250 and 300 ppm within 120, 130, 130, 150, 140 and 150 minutes and the maximum metal capacities are 11.29, 20.90, 19.50, 28.33, 29.93, 31.90 mg/g respectively.

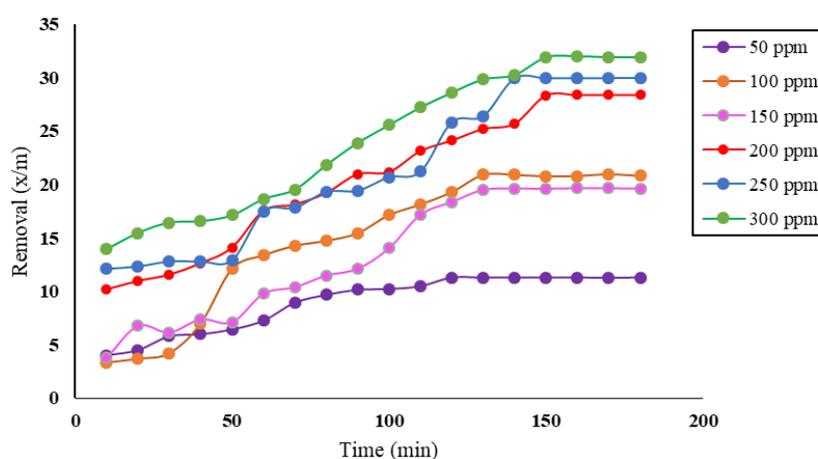


Fig. 8. Effect of contact time for the removal of Fe³⁺ ions by using BFAC

To determine Langmuir parameters, a graph of C_e/Q_e vs C_e were explored (Figure 9). By using equation 4, the evaluated parameters such as Langmuir isotherm constants and their correlation coefficient R^2 are given in Table 1. The value of R^2 confirmed that this adsorption

is favorable for Langmuir model (Chakrabarty, et al., 2017) and the surface of BFAC is with heterogeneous energies i.e., different parts of BFAC surface has different types of energies to attract Fe^{3+} ions onto it.

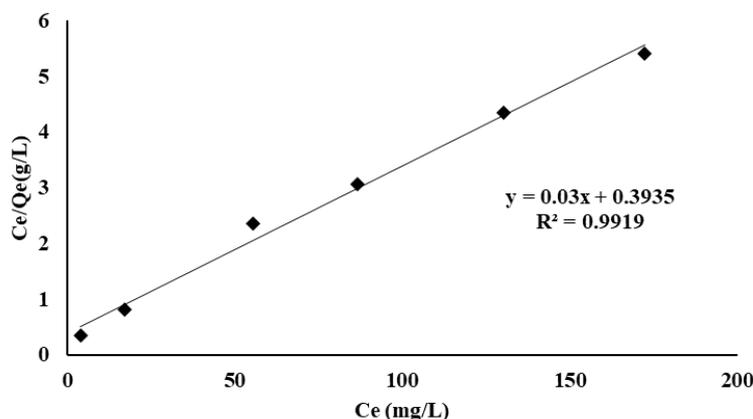


Fig. 9. Langmuir plot for the adsorption of Fe^{3+} ion onto BFAC

Using equation 5, Freundlich parameters was determined from the plot of $\log Q_e$ against $\log C_e$ (Figure 10). The adsorption of Fe^{3+} ion onto BFAC showed a straight line. The value of n was 3.9; represented a good adsorption (Yu et al., 2011). Table 1 demonstrates the Freundlich adsorption isotherm constants and their correlation coefficient R^2 . This values also says that from the beginning of the adsorption, multi molecular layer was formed instead of monolayer (Chakrabarty, et al., 2017).

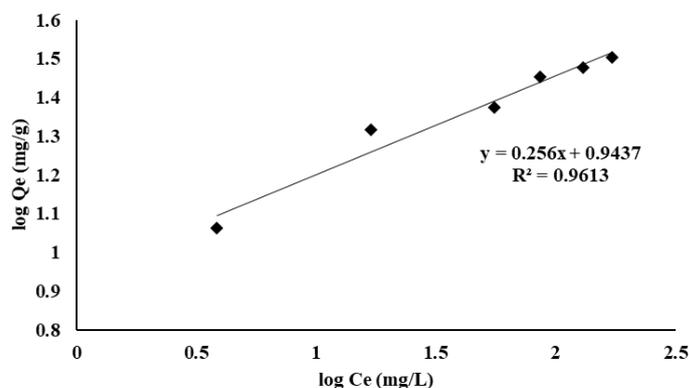


Fig. 10. Freundlich plot for the adsorption of Fe^{3+} ion onto BFAC

To study Temkin isotherm equation 6 was used. The Temkin isotherm constants a_T and b_T (Table 1) were determined from the slope and intercept of q_e versus $\log C_e$ plot (Figure 11). The regression correlation coefficient for the Temkin isotherm model was 0.9783, which indicated that the Temkin isotherm model did also fit well with the experimental data (Akkaya et al., 2005). In summary, the regression coefficients (R^2) were 0.9613 for the Freundlich isotherm, 0.9919 for the Langmuir isotherm, and 0.9783 for the Temkin isotherm. The R^2 values indicated that while each isotherm had its own merits in describing the removal of Fe^{3+} ions by BFAC, the Langmuir isotherm was the best followed by the Freundlich isotherm. The Temkin isotherm did also agree well with the adsorption process (Akkaya et al., 2005).

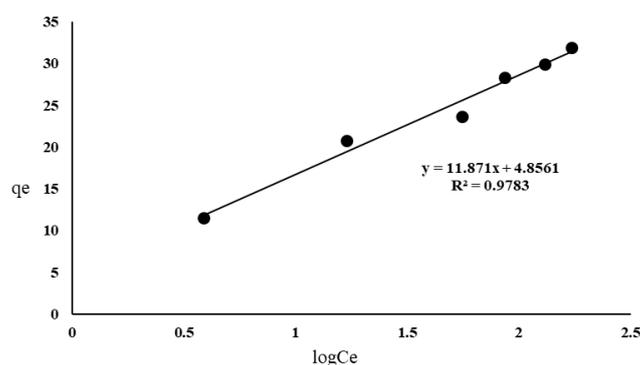


Fig. 11. Temkin isotherm for the adsorption of Fe^{3+} ions by BFAC

Table 1. Coefficients determination of (R^2) and isotherm constants for the Langmuir, Freundlich and Temkin isotherm models for the adsorption of Fe^{3+} ions by BFAC

Metal ion	Adsorbent	Langmuir isotherm constant			Freundlich isotherm constant			Temkin isotherm constant		
		b	Q_m (mg/g)	R^2	k	n	R^2	B_T	a_T	R^2
Fe^{3+}	BFAC	0.076	33.33	0.9919	8.78	3.90625	0.9613	11.871	2.564	0.9783

Table 2. Iodine number and the values of Langmuir and Freundlich Adsorption model co-efficient of BFAC in comparison with other activated charcoals

Activated Charcoal	Removal of metal ion	Iodine value mg/g	Freundlich constant		Langmuir constant R^2	Reference
			n	R^2		
Sugarcane Bagasse Deuterium	Fe^{3+}	611.768	4.5	0.8577	0.9609	Syed et al., 2020
microcarpum and Balanitea egyptiaca shells	Fe^{3+}	-	0.69	0.6261	0.8492	Wyasu et al., 2016
Date Pits	Fe^{3+}	259.20	2.90	0.946	0.998	Awwad et al., 2008
Coconut Wastes (Shell)	Fe^{3+}	310.98	2.22	0.981	0.912	Livinus, et al., 2018
Coconut Wastes (Coir)	Fe^{3+}	203	1.629	0.908	0.966	Livinus, et al., 2018
Commercial charcoal	Fe^{2+}	264.4	2.71	0.85	0.94	Kouakou et al., 2013
Borassus flabellifer	Fe^{3+}	691.88	3.90	0.9613	0.9919	This work

Table 2 represents iodine number and the values of Langmuir and Freundlich adsorption model constant of BFAC with other activated charcoal. It is seen that, among the presented values, the iodine number of BFAC is highest. The value of n is appreciably high and close to sugarcane bagasse, which has the highest value and the values of Freundlich and Langmuir constant R^2 is appreciably acceptable.

For Lagergren model, a graph of $\log(q_e - q_t)$ versus t (Figure 12) was studied using Eq. 7, revealed that it was linear and represented the pseudo first-order kinetics for the removal of Fe^{3+} ion using BFAC. The calculated values of the first-order rate constants k_1 and q_e are tabulated in Table 3. The regression correlation coefficient was 0.9567 which was good and showed the applicability of the pseudo first-order kinetic model to the removal of Fe^{3+} ions using activated charcoal. The experimental values of q_e obtained 11.31 which did agree with the values predicted by the pseudo first-order model (Tabak et al., 2009).

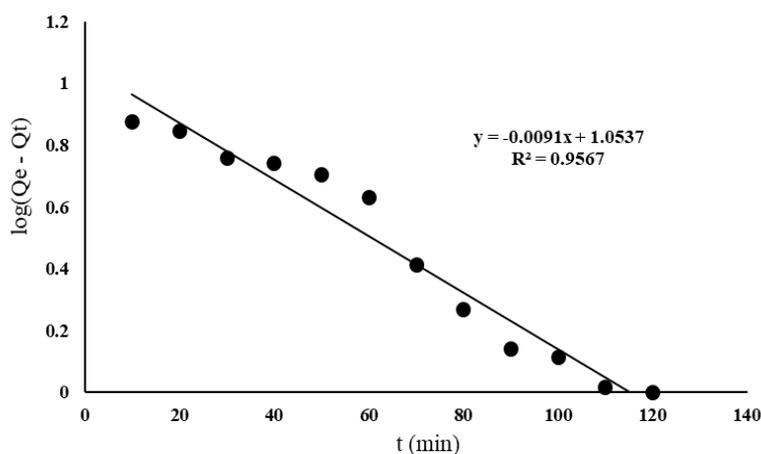


Fig. 12. Pseudo first-order kinetics plot for the adsorption of Fe^{3+} ions onto BFAC

To evaluate the pseudo second-order adsorption kinetic model, equation 8 was used, a graph of (t/q_t) versus t (Figure 13) were well-thought-out. It was seen that the plot is linear. The calculated values of q_e disagreed with the experimental values (Table 3), and the values obtained for the regression correlation coefficients was 0.9093 (Tabak et al., 2009). These results indicated that the kinetics of Fe^{3+} ion adsorption using activated charcoal were explained better by a 1st order kinetic model than a 2nd order one (Tabak et al., 2009).

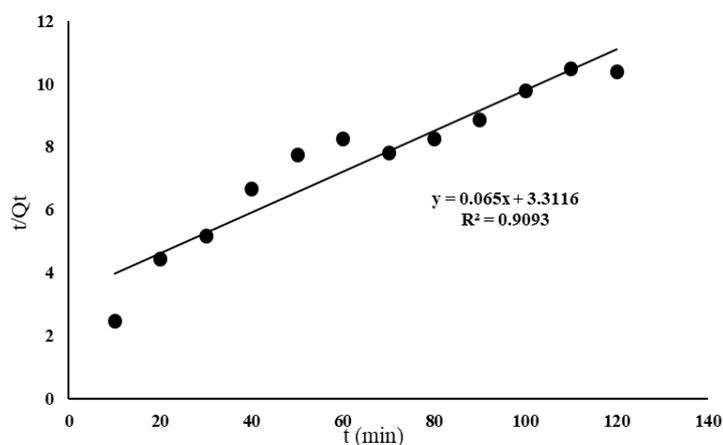


Fig. 13. Pseudo second-order kinetics plot for the adsorption of Fe^{3+} ions onto BFAC

For Elovich equation, a graph of qt versus $\ln t$ (Figure 14) were assessed using Eq. 9. The slope and intercept were used to determine the kinetic constants α and β , respectively, and the regression correlation coefficients were calculated (Table 3). It was seen that the regression correlation coefficients for the 1st order kinetic model were greater than those for the pseudo 2nd order and Elovich kinetic model. That again indicated that the adsorption of Fe^{3+} ion from aqueous solution onto BFAC is followed by 1st order kinetic model (Sika et al., 2010).

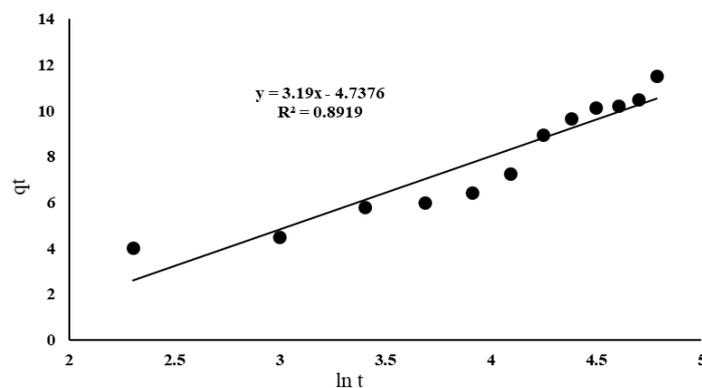


Fig. 14. Elovich's plot for kinetic modeling of the adsorption of Fe^{3+} ions onto BFAC

Table 3. Kinetic constants for pseudo first-order, pseudo second-order, and Elovich models for the adsorption of Fe^{3+} ions by BFAC

q_e (experimental) mg/g	Pseudo first-order kinetics model			Pseudo second-order kinetics model			Elovich kinetic model		
	q_e (theoretical) mg/g	k_1 (per min)	R^2	q_e (theoretical) mg/g	k_2 (g/h.mg)	R^2	α	β	R^2
11.53	11.31	0.0209	0.9567	15.38	0.00127	0.9093	0.071	0.313	0.8919

The production cost of BFAC has been compared with other commercially available activated charcoals and summarized in Table 4. From this table it can be seen that the prices of previously reported adsorbents ranged between 1.44 to 22 \$/kg. On the other hand, the production cost of BFAC is only 0.5-0.625 \$/kg, which is much cheaper than the others. Therefore, BFAC could be considered as cost-effective adsorbent for the sequestration of Fe^{3+} from wastewater.

Table 4. Prices of activated charcoals

Source derived activated charcoal	Cost of production/price (US \$/kg)	References
Rice husk	3.58-3.77	Song et al., 2012
Rice bran	3.54	Suzuki et al., 2007
Pecan shells	2.72	Ng et al., 2003
Sugarcane bagasse	3.12	Ng et al., 2002
Almond shells	2.56-2.93	Toles et al., 2000
Commercial activated carbon	20-22	Toles et al., 2000
Wood	2.49	Stavropoulos and Zabaniotou, 2009
Bamboo scaffolding waste	1.93	Choy et al., 2005
Artocarpus integer fruit processing waste	1.67	Selvaraju and Bakar, 2017
Lignite	2.18	Stavropoulos and Zabaniotou, 2009
Broiler litter based carbon	1.44	Lima et al., 2008
BFAC	0.5- 0.625	This work

CONCLUSION

In this study, a very easy and cost effective method, carbonization, was applied for the preparation of activated charcoal, BFAC, from locally available raw material BF male flower

in the southwestern part of Bangladesh. SEM and EDX was used to see the surface morphology of BFAC. Its surface was negatively charged as confirmed by zero point charge value and showed high activation as confirmed by iodine number method. A batch adsorption study was performed using UV-Visible spectroscopy. Adsorption isotherms and kinetic models were tested. The results from batch adsorption study showed good agreement with both Langmuir and Freundlich adsorption isotherm and had better fitting with 1st order rate reaction. Here, no costly instrumentation is needed for BFAC preparation. To increase its surface area hand milling is enough. This charcoal could be used in rural areas in Bangladesh where iron contamination is high in drinking water and general people can prepare this charcoal easily only they have BF male flower which is available in all areas in Bangladesh. So, it can be said that, for the preparation of activated charcoal and removal of iron from water, BF is far available as well as BFAC is cost effective and commercially adaptable in practical approach.

GRAND SUPPORT DETAILS

The present research has been financially supported by Research Cell of Khulna University, Khulna-9203, Bangladesh (Grant No. KU/RCell-04/2000-57).

CONFLICTS OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

REFERENCES

- Akkaya, G. and Ozer, A. (2005). Adsorption of acid red 274 (AR 274) on *Dicranella varia*: determination of equilibrium and kinetic model parameters. *Proc. Biochem.*, 40; 3559-3568.
- Allwar, A. (2016). Preparation and characteristics of activated carbon from oil palm shell for removal of iron and copper from patchouli oil. *Int. J. Appl. Chem.*, 12 (3); 183-192.
- Ara, M. H., Mondal, U. K., Dhar, P. K. and Uddin M. N. (2018). Presence of Heavy Metals in Vegetables Collected from Jashore, Bangladesh: Human Health Risk Assessment. *JCHR.*, 8(4); 277-287.
- Awwad, N. S., Daifuallah, A. A. M. and Ali, M. M. S. (2008). Removal of Pb²⁺, Cd²⁺, Fe³⁺, and Sr²⁺ from Aqueous Solution by Selected Activated Carbons Derived from Date Pits. *Solvent Extr. Ion Exc.*, 26; 764-782.
- Aziz, M. H. A., Gutub, S., Soliman, M. F. and Bassyouni, M. (2016). Removal of Fe⁺⁺ from Wastewater Using Sludge-polymer Hybrid Adsorbents. *Environ. Prot.*, 18; 28-45.
- Baseri, J. R. (2012). Preparation and characterization of activated carbon from the vetia peruviana for the removal of dyes from textile waste water. *Adv. Appl. Sci. Res.*, 3; 377-383.
- Beenakumari, K. S. (2009). Removal of iron from water using modified coconut shell charcoal as adsorbent. *Curr World Environ.*, 4(2); 321-326.
- Bernard, E., Jimoh, A. and Odigure, J.O. (2013). Heavy Metals Removal from Industrial Wastewater by Activated Carbon Prepared from Coconut Shell. *Res. j. chem. Sci.*, 3(8); 3-9.

- Biswas, R. K., Roy, M. K. and Haque, K. I. (2013). Assessment of Groundwater Quality for Drinking Purpose in Some Parts of Jhenaidah District, Bangladesh. IJGEES., 3(1); 195-204.
- Chakrabarty, S., Mahmud, M. A., Ara, M. H. and Bhattacharjee, S. (2021). Development of a Platform for Removal of Iron (III) Ions from Aqueous Solution Using CuO Nanoparticles. J. Water Environ. Nanotechnol., 6(1); 41-48.
- Chakrabarty, S., Tonu, N. T. and Saha, N. K. (2017). Removal of Iron (II) ion from Aqueous Solution Using Waste Tea Leaves. Int. J. Eng. Sci., 6(12); 62-67.
- Chaturvedi, S. and Dave, P. N. (2012). Removal of Iron for Safe Drinking Water, Desalination., 303(1); 1-11.
- Choy, K. K. H., Barford, J. P., and McKay, G. (2005). Production of activated carbon from bamboo scaffolding waste—process design, evaluation and sensitivity analysis. Chem. Eng. J., 109(1–3); 147–165.
- Dahlan, I., Hassan, S. R. and Hakim, M. L. (2013). Removal of iron (Fe^{2+}) from aqueous solutions using siliceous waste sorbent, Sustain. Environ. Res., 23(1); 41-48.
- Dhanik, J. and Kumar, S. (2017). Adsorption study of Fe^{2+} ions in presence of co-metal ions from aqueous solution on Cuscuta powder. Int. J. Chem. Stud., 5(4); 1062-1066.
- Ekpete, O. A., Marcus, A. C. and Osi, V. (2017). Preparation and Characterization of Activated Carbon Obtained from Plantain (*Musa paradisiaca*) Fruit Stem. J. Chem., 2017; 1-6.
- Ghaedi, M., Biyareh, M. N., Kokhdan, S. N., Shamsaldini, S., Sahraei, R., Daneshfar, A. and Shahriyar, S. (2012). Multiwalled Carbon Nanotubes as Adsorbents for the Kinetic and Equilibrium Study of the Removal of Alizarin Red S and Morin. Mater. Sci. Eng., 32; 725-734.
- Gil, R. A., Kaplan, M. M., Salonia, J. A., G'asquez, J. A. and Martinez, L.D. (2007). Total Inorganic Se and Te Preconcentration and their Determination by On-Line Coupling of a Solid-Phase Extraction Procedure with HG-AAS. At. Spectrosc., 28(2); 67-72.
- Igwe, J. C., Abia, A. A. and Maize. (2003). Cob and Huks As Adsorbents for the Removal of Cadmium, Lead and Zinc Ions from Wastewater. Phys. Sci., 2; 83-92.
- Iman, E. S., Nady, A. F. and Adli, A. H. (2013). Removal of Mn (II) and Fe (II) ions From Aqueous Solution Using Precipitation and Adsorption Methods. J. Appl. Sci. Res., 9; 233-239.
- Khan, M. N. and Sarwar, A. (2007). Determination of points of zero charge of natural and treated adsorbents. J. Surf. Rev. Lett., 461-469.
- Kouakou, U., Ello, A. S., Yapo, J. A. and Trokourey, A. (2013). Adsorption of iron and zinc on commercial activated carbon. JECE., 5(6); 168-171.
- Lima, I. M., McAloon, A., and Boateng, A. A. (2008). Activated carbon from broiler litter: Process description and cost of production. Biomass & Bioenergy., 32(6); 568–572.
- Livinus, A., Obasi, A. O., and Cornelius, O. Nevo. (2018). Adsorption Isotherm and Kinetics for the Removal of Fe^{3+} from Aqueous Solution using Activated Coconut Wastes. JCHPS., 5(4); 29-35.
- Lo, S. F., Wang, S. Y., Tsai, M. J. and Lin, L. D. (2012). Adsorption Capacity and Removal Efficiency of Heavy Metal Ions by Moso and Ma Bamboo Activated Carbons. Chem. Eng. Res. Des., 90; 1397-1406.
- Magda, A. A., Yousef, A. M. and Abdelnasser. (2013). Removal iron and manganese from water samples using activated carbon derived from local agro-residue. J. Chem. Eng. Pro. Technol., 4(4); 154-163.
- Mamun, K. R., Saha, N. K. and Chakrabarty, S. (2019). A Comparative Study of the Adsorption Capacity of Tea Leaves and Orange Peel for the Removal of Fe (III) ion from Waste water. J. Chem. Health Risks., 9(2); 107-115.
- Mehmet, E. A., Sukru, D., Celalettin, O. and Mustafa, K. (2006). Heavy metal adsorption by modified oak sawdust. J. of Hazard. Mater., In Press.
- Meril, D., Shamim, A., jahan, A., Cristian, B. and West, P. (2012). Ground water iron assessment and consumption by women in rural northwestern Bangladesh. Int J Vitam Nutr Res., 82; 5-14.
- Modin, H., Persson, K. M., Andersson, A. and Praagh, M. V. (2011). Removal of Metals from Landfill Leachate by Sorption to Activated Carbon, Bone Meal and Iron Fines. J. Hazard. Mater., 189(3); 749-754.

- Namasivayam, C. and Sureshkumar, M. V. (2008). Removal of Chromium (VI) from Water and Wastewater Using Surfactant Modified Coconut Coir Pith as a Biosorbent. *Bioresour. Technol.*, 99(7); 2218-2225.
- Ng, C., Bansode, R. R., Marshall, W. E., Losso, J. N., and Rao, R. M. (2002). Process description and product cost to manufacture sugarcane bagasse-based granular activated carbon. *Int. Sugar J.*, 104(1245); 401-408.
- Ng, C., Marshall, W. E., Rao, R. M., Bansode, R. R., and Losso, J. N. (2003). Activated carbon from pecan shell: Process description and economic analysis. *Ind. Crops Prod.*, 17(3); 209-217.
- Ojha, A. K. and Bulasara, V. K. (2015). Adsorption Behavior of Methylene Blue onto Powdered Ziziphus Lotus Fruit Peels and Avocado Kernels Seeds. *Progress Sustain Ener.*, 34 (2); 461-470.
- Osemeahon, S.A., Barminas, J.T. and Adama M.A. H. (2013). Studies on the removal of metal ions from aqueous solution using Immobilized *Bombax costatum* calyx. *IOSR Journal Of Environmental Science, Toxicol. Food Technol.*, 3(6); 6-13.
- Öztaş, N. A., Karabakan, A. and Topal, Ö. (2008). Removal of Fe(III) Ion from Aqueous Solution by Adsorption on Raw and Treated Clinoptilolite Samples. *Microporous and Mesoporous Mater.*, 11; 200-205.
- Qian, G., Li, M., Wang, F. and Liu, X. (2014). Removal of Fe³⁺ from Aqueous Solution by Natural Apatite. *J Surf Eng Mater Adv Technol.*, 4; 14-20.
- Rana, P., Sohel, S., Islam, S., Akhter, S., Chowdhury, M. S., Alamgir, M. and Koike, M. (2009). Traditional Practice of palm husbandry in the southeastern region of rural Bangladesh. *Int J Biodivers Sci Ecosyst Serv Manag.*, 5(3); 155-161.
- Rekha, D., Suvadhan, K., Kumar, K. S., Reddyprasad, P., Jayaraj, B. and Chiranjeevi, P. (2007). Extractive Spectrophotometric Determination of Copper(II) in Water and Alloy Samples with 3-Methoxy-4-Hydroxy Benzaldehyde-4-Bromophenyl Hydrazone (3,4-MHBBPH). *J. Serb. Chem. Soc.*, 72(3); 299-310.
- Rose, E. P. and Rajam, S. (2012). Equilibrium study of the adsorption of iron (II) ions from aqueous solution on carbons from wild jack and jambul. *Adv Appl Sci Res.*, 3(2); 1889-1894.
- Salehzadeh, J. (2013). Removal of Heavy Metals Pb²⁺, Cu²⁺, Zn²⁺, Cd²⁺, Ni²⁺, Co²⁺ and Fe³⁺ from Aqueous Solutions by using *Xanthium pennsylvanicum*. *Leonardo J Sci.*, 2013(23); 97-104.
- Sarin, P., Snoeyink, V. L., Bebee, J., Jim, K. K., Beckett, M. A. and Kriven, W. M. (2004). Iron Release from Corroded Iron Pipes in Drinking Water Distribution Systems: Effect of Dissolved Oxygen. *Water Res.*, 38(5); 1259-1269.
- Selatnia, A., Boukazoula, A., Kechid, N., Bakhti, M. Z. and Chergui, A. (2004). Biosorption of Fe³⁺ from Aqueous Solution by a Bacterial Dead *Streptomyces Rimosus* Biomass. *Process Biochem.*, 39(11); 1643-1651.
- Selvaraju, G., and Bakar, N. K. A. (2017). Production of a new industrially viable green-activated carbon from Artocarpus integer fruit processing waste and evaluation of its chemical, morphological and adsorption properties. *J. Clean. Prod.*, 141; 989-999.
- Shama, S.A., Gad, M.A. (2010). Removal of Heavy Metals (Fe³⁺, Cu²⁺, Zn²⁺, Pb²⁺, Cr³⁺ and Cd²⁺) from Aqueous Solutions by Using Hebba Clay and Activated Carbon. *Port. Electrochim. Acta.*, 28(4); 231-239.
- Sheibani, A., Shishehbor, M. R. and Alaei, H. (2012). Removal of Fe³⁺ Ions from Aqueous Solution by Hazelnut Hull as an Adsorbent. *Int. J. Ind. Chem.*, 3; 1-4.
- Shrestha, R. M., Yadav, A. P., Pokharel, B. P. and Pradhananga, R. R. (2012). Preparation and characterization of activated carbon from Lapsi (*Choerospondiasaxillaris*) seed stone by chemical activation with phosphoric acid. *Res. J. Chem. Sci.*, 2; 80-86.
- Sika, M. S. A., Liu, F. and Chen, H. (2010). Optimization of key parameters for chromium (VI) removal from aqueous solutions using activated charcoal. *J. Soil. Sci. Environ. Manage.*, 1(3); 55-62.
- Song, X., Zhang, Y., and Chang, C. (2012). Novel Method for Preparing Activated Carbons with High Specific Surface Area from Rice Husk. *Ind. Eng. Chem. Res.*, 51(46); 15075-15081.
- Stavropoulos, G. G., and Zabaniotou, A. A. (2009). Minimizing activated carbons production cost. *Fuel Process. Technol.*, 90(7-8); 952-957.

- Suzuki, R. M., Andrade, A. D., Sousa, J. C., and Rollemberg, M. C. (2007). Preparation and characterization of activated carbon from rice bran. *Bioresour. Technol.*, 98(10); 1985–1991.
- Syed, A., Kumar, G., Tonu, N. T., Chakrabarty, S., Mahiuddin, M. and Hoque, K. (2020). An Investigation of the Adsorption Capacity of Carbon Particle for the Removal of Fe^{3+} ion from Water. *Int. J. Chem. Stud.*, 8(2); 55-61.
- Tabak, A., Eren, E., Afsin, B. and Caglar, B. (2009). Determination of adsorptive properties of a Turkish Sepiolite for removal of Reactive blue 15 anionic dye from aqueous solutions. *J. Hazard. Mater.*, 161; 1087-1094.
- Toles, C. A., Marshall, W. E., Wartelle, L. H., and McAloon, A. (2000). Steam- or carbon dioxide-activated carbons from almond shells: Physical, chemical and adsorptive properties and estimated cost of production. *Bioresour. Technol.*, 75(3); 197–203.
- Wang, J. and Chen C. (2009). Biosorbents for Heavy Metals Removal and Their Future. *Biotechnol. Adv.*, 27; 195-226.
- Wyasu, G., Gimba, C. E., Agbaji, E. B. and Ndukwe, G. I. (2016). Adsorption of Cr^{6+} and Fe^{3+} from Hospital Wastewater Using Activated Carbon from Epicarp of *Detarium Microcarpum* and *Balanitea Egyptiaca* Shells. *J. chem. pharm.*, 8(3); 92-99.
- Yu, F., Ma, J. and Wu, Y. Q. (2011). Adsorption of Toluene, Ethyl Benzene and M-Xylene on Multi-Walled Carbon Nanotubes with Different Oxygen Contents from Aqueous Solutions. *J. Hazard. Mater.*, 192; 1370-1379.
- Zaini, M. A. A., Amano, Y. and Machida, M. (2010). Adsorption of Heavy Metals onto Activated Carbons Derived from Polyacrylonitrile Fiber. *J. Hazard. Mater.*, 180(13); 552-560.
- Zhang, Z., Xiao, C., Adeyeye, O., Yang, W. and Liang, X. (2020). Source and Mobilization Mechanism of Iron, Manganese and Arsenic in Ground Water of Shuangliao City, Northeast China. *Water.*, 12; 534.

