

Research Article

Effective Utilization of Eichhornia Crassipes in Decolourisation of Cationic dyes from aqueous solution

S Kalai Selvi^{1*} and N Suganthi²¹Department of Chemistry, Velalar College of Engineering and Technology, Erode, Tamilnadu, India²Department of Chemistry, L.R.G Govt Arts College for Women, Tirupur, Tamilnadu, India**Abstract**

Adsorption is an ideal alternative technique to other expensive treatment options for removal of colour from wastewaters. In this study Eichhornia Crassipes, an aquatic weed was used as a raw material to prepare activated carbon by various methods according to the standard procedures. The effects of different system variables were studied in the batch tests using Methylene blue and malachite green dyes at different dilutions with the Eichhornia Crassipes carbon. In-order to develop an effective and accurate design for removal of dye, adsorption kinetics and equilibrium data are essential basic requirements. Results of the kinetic studies show that the adsorption reaction is second-order kinetic model. Elovich model and intra particular diffusion corresponding constants were calculated and discussed. Equilibrium isotherms were analyzed by Langmuir, Freundlich and Tempkin isotherms. The adsorption equilibrium data obeyed Langmuir, Freundlich, Tempkin isotherms. Desorption and use of desorbed datas has been obtained.

Keywords: Cationic dyes, Eichhornia Crassipes, Adsorption and Isotherm

***Correspondence**

Author: S Kalai Selvi

Email: kalaiprony@gmail.com

Introduction

One of the world's most polluting industries is the textile-dyeing sector, which in Asian nations releases trillions of liters of chemically tainted wastewater. Each year, textile-dyeing industry gulps down trillions of liters of fresh water, together with massive amounts of chemicals. The untreated wastewater from those industries is then dumped into rivers that bring its toxic content to the sea, where it spreads around the globe [1]. Methylene blue (MB) is synthetic aromatic complex, used for many textile and dyeing industries. MB damages eye, on gasp causes headache, acute breathing problems, increases sweating and heart rate. On ingest causes abdominal pain, mild bladder irritation, dizziness, vomiting, stomach upset and frequent urination [2]. Malachite Green (MC) is a cationic dye, used for the textile, paper and leather dyeing industries. It has many medicinal values like antimicrobial in aquaculture to enlarge fish hatchery. It is also used as food coloring and additives in food processing units. In 1992, eating fish containing traces of malachite green as contaminants cause significant health hazards in human being was suggested by Canadian authorities [3]. In June 2007, the Food and Drug Administration (FDA) blocked the importation of several varieties of seafood due to continued malachite green contamination [4]. MC is injurious to eyes, skin, bones, and stomach. On ingestion causes anemia, diarrhea, infertility, abdominal pain and irritation to heart, kidney, stomach and lungs. It also reduces RBC count and raise WBC count, which delays coagulation of blood [5]. In particular, these dyes are synthetic aromatic compounds; which are highly toxic, carcinogenic or mutagenic to life forms [6]. The presence of even very low concentration of dyes makes water highly colored and aesthetically undesirable. Therefore colour should be removed from the effluent before they are discharged.

Adsorption with activated carbon has been proved to be an effective and attractive process for the treatment of colored waste water. Countries like India; there is a need to search for a new class of cost-effective materials. In recent years attention has been focused on agricultural waste annually. There are numerous agricultural by products and residues have been proved to remove dyes from aqueous solution [7]. Identifying new, economical, highly effective and abundantly available material is still needed.

Eichhornia crassipes (*Water hyacinth*) constitutes an important part of an aquatic ecosystem. The direct effect of Eichhornia Crassipes on freshwater bodies is its obnoxious smell. It kills the aquatic biota also and depletes oxygen completely from water streams. Water hyacinth as a very promising plant with tremendous application in wastewater treatment is already proved. Water hyacinth is used to treat wastewater from dairies, tanneries, sugar factories, pulp and paper industries, palm oil mills, distilleries, etc [8]. All the efforts of scientists and technocrats all over the world

to eliminate these weeds by chemical and biological means have met with little success [8]. Due to ecological devastating properties of Eichhornia Crassipes, it is used for wastewater treatment. This has motivated us to take the plant for adsorption studies, which will possibly eradicate the abundance of an invasive organism. Desorption of exhausted carbon are economical feasible. Using regenerated carbon reduces the cost of purchase of fresh activated carbon. In order to keep the desorbed carbon not another pollutant it was used for its constructive property mixed with cement. In this work, an attempt was made to remove of cationic dyes from aqueous solutions using a new adsorbent prepared from Eichhornia Crassipes.

Experimental section

Materials

Eichhornia crassipes has been collected from nearby water sources and treated with 10% Solution of chloride salts (CaCl_2 , ZnCl_2 , MnCl_2 & NH_4Cl), 10 % solution of sodium sulphate sand ammonium sulphates, 10% solution of sodium carbonate, potassium carbonate, dolomite and concentrated phosphoric acid.

Preparation of carbon from Eichhornia crassipes

The collected Eichhornia crassipes was repeatedly washed with water to remove any earthy and dusty impurities present in it and then dried at 110°C in air oven. The dried Eichhornia crassipes was impregnated was treated with concentrated Phosphoric acid in the ratio 2:1 and kept in an oven at 160°C for 24 hours. It was then washed repeatedly with distilled water to remove free phosphoric acid. During the last washing two drops of ammonium molybdate is added to test the presence of phosphoric acid. Then it is subjected to thermal activation at 800°C for 15 minutes. The carbon prepared was powered, sieved and particles in the range 75 – 300 μm mesh size were retained for the evaluation of different carbon characteristics (Table 1).

Table 1 Carbon Characteristics

Control Tests	Experimental Values
Bulk density g/cc	0.29
Moisture %	4.1
Ash %	1.97
Fixed carbon content	94.07
Matter soluble in water (%)	1.11
Matter soluble in acid (%)	2.35
pH	5.2
Decolorizing power (mg /g)	31.50
Phenol number (mg)	20.0
Ion exchange capacity (meq/ g)	6.73
Iron content [^]	0.0699
Surface area m^2/g	320

Results and discussion

Scanning electronic images

The surface morphology of the prepared activated carbon sample surface was examined using Scanning Electron Micrographs. These micrographs (Figure 1) gives an appreciation of the porosity of an adsorbent and hence a qualitative assessment of their ability to adsorb the dye molecules in solution. The prepared activated carbon mainly contains considerable micropores, also containing a certain quantity of mesopores. It is thus clear that, the prepared activated carbon contains redundant pore structure was further proved convincingly by SEM. The images were measured before and after the adsorption of Methylene blue and Malachite Green (MB and MG) onto the adsorbent.

FT-IR spectroscopy

The FTIR pattern was an important tool to identify some important functional groups, which are capable of adsorbing pollutant ions. FTIR spectroscopy was, therefore, done for preliminary quantitative analysis of major functional groups presented in ECAC. The FTIR spectrum of ECAC, before and after MB and MG adsorption is shown in Figure 2.

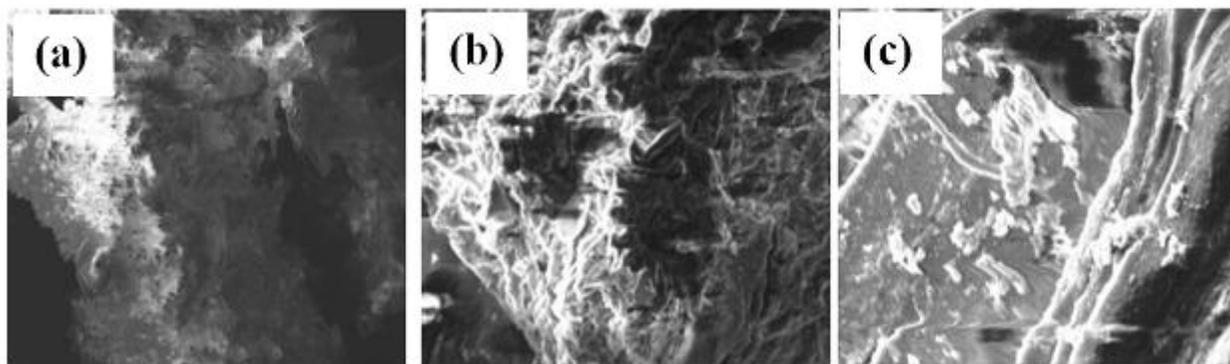


Figure 1 SEM observations of: (a) ECAC before adsorption, (b) ECAC after adsorption by MB and (c) ECAC after adsorption by MG

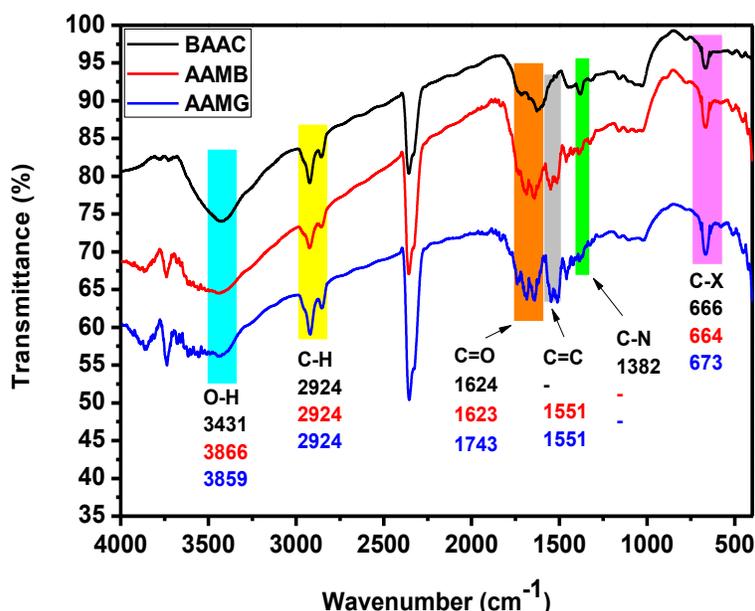


Figure 2 FT-IR analysis of (a) ECAC before adsorption, (b) ECAC after adsorption by MB (c) ECAC after adsorption by MG

The FTIR spectra before (BA) and after sorption (AA) of MB and MG were used to determine the vibrational frequency changes in the functional groups present in the adsorbent. The spectra of adsorbents were measured within the range from 600–4000 cm^{-1} wave number. The spectra were plotted using the same scale on the transmittance axis for all the adsorbents before and after adsorption. From the FTIR spectra, it is clear that the adsorbent displays a number of absorption peaks, reflecting the complex nature of the adsorbent.

Table 2 shows the tabulated data for FTIR spectra band assignments for BAAC, AAMB and AAMG samples obtained from Figure 2. These spectral lines describe the various changes that occurred in the BAAC, AAMB and AAMG samples. The results indicate that some peaks were shifted or disappeared, and the new peaks are also detected in AAMB and AAMG samples. These changes observed in the spectrum indicate the possible involvement of those functional groups on the surface of the ECAC in adsorption process.

Table 2 FTIR spectral band assignments for BAAC, AAMB and AAMG

Assignment	Band Position in cm^{-1}		
	BAAC	AAMB	AAMG
O–H stretching of hydroxyl group	3431.87	3866.34 - 3449.23	3859.59 - 3740.49
C–H stretching in alkanes or alkyl group	2924.59 - 2357.51	2924.59 - 2360.41	2924.11 - 2358.96
C=O stretching of anhydride	1624.56	1693.51 - 1643.85	1743.66 - 1638.54
C=C of aromatic ring	-	1551.75 - 1462.05	1551.75 - 1462.05
C–N stretching of aliphatic 1 ^o amine	1382.49 - 1030.96	-	-
C–X stretching of carbon halogen group	666.41	664.48	673.16 - 643.27

Point Zero charge

The point of zero charge (pH_{PZC}) can be used to characterize an adsorbent material, since it indicates the pH at which the adsorbent material has a net zero surface charge [6]. The adsorbent surfaces have a net positive charge at $pH < pH_{PZC}$, while at $pH > pH_{PZC}$, the surfaces have a net negative charge [9]. The determination of pH_{PZC} of cedar sawdust, pine sawdust, straw, and Provence cane was performed according to the solid addition method [10] described as follows: 45 mL of 0.01 M KNO_3 solution was placed in conical flasks. The initial pH of solutions was adjusted from 2 to 12 by adding 0.1N HCl or NaOH. Then, 1 g of used adsorbent was added to each flask, the mixture was stirred, and the final pH of the solutions was measured after 24 h. The points of intersection of the resulting curve obtained by plotting a graph between pH_i vs ΔpH (Figure 3) was found to be 7 and 9 for MB and MG respectively.

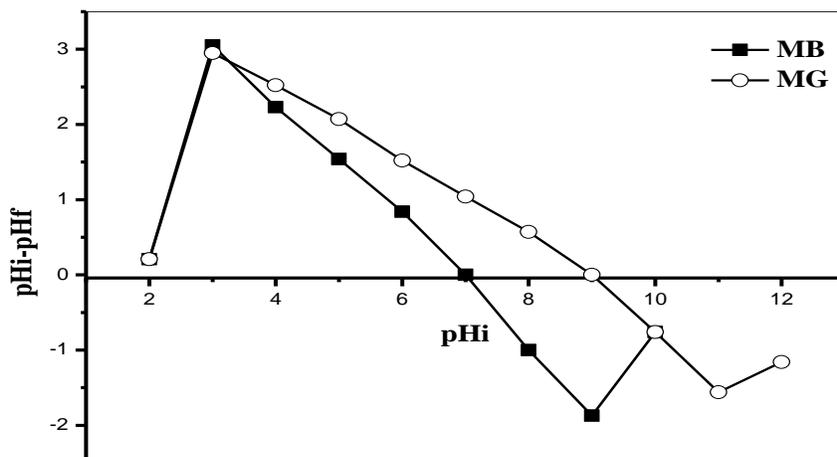


Figure 3 Point of Zero Charge

Effect of Carbon Dosage

Results of the effect of carbon mass (Figure 4) indicate a rapid increase in the adsorption rate of both MB and MG as the dose of carbon increases from 50 to 300 mg. This reflects the relative dependence between adsorption of MB and MG and the dose of activated carbon. The increase in the percent removal of dyes observed with increasing carbon dosage is due to the increasing number of available adsorption sites of used adsorbent. For the following studies 10 g/L was taken as optimum carbon dosage.

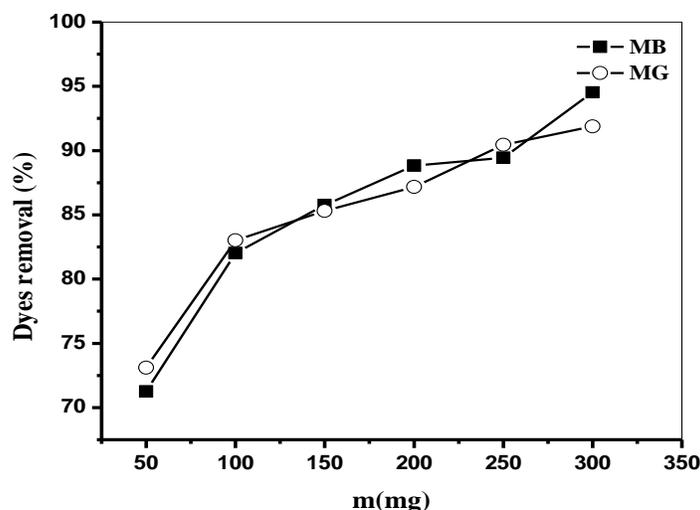


Figure 4 Effect of Carbon Dosage

Effect of pH

The influence of the aqueous solution pH on the adsorption behavior of the dye onto various adsorbents was considered by many authors [11-13] which is one of the most important factors affecting the adsorption process. In order to investigate the influence of pH on the MB and MG removal by ECAC adsorbent, experiments were carried

out at pH values ranging from 2 to 12 at a fixed MB and MG concentration of 100 mg L^{-1} . **Figure 5** showed that the acidity of the medium has generally a dramatic effect on the yield of MB and MG adsorption and the removal percentage increases with increasing pH solutions. The very low adsorption capacity at strong acidic pH is mainly due to the presence of an excess of H^+ ions which compete with the cationic dyes for the active sites [9]. When the pH is increased to values higher than the pH_{PZC} of ECAC adsorbent, the number of negatively charged sites on the surface adsorbent increases and the removal percentage of MB and MG also increases. This could be attributed due to the increase in the electrostatic attractions between cationic dyes and the adsorbent's functional groups. Therefore, the $\text{pH}=7$ of MB and MG solutions, was selected for further studies.

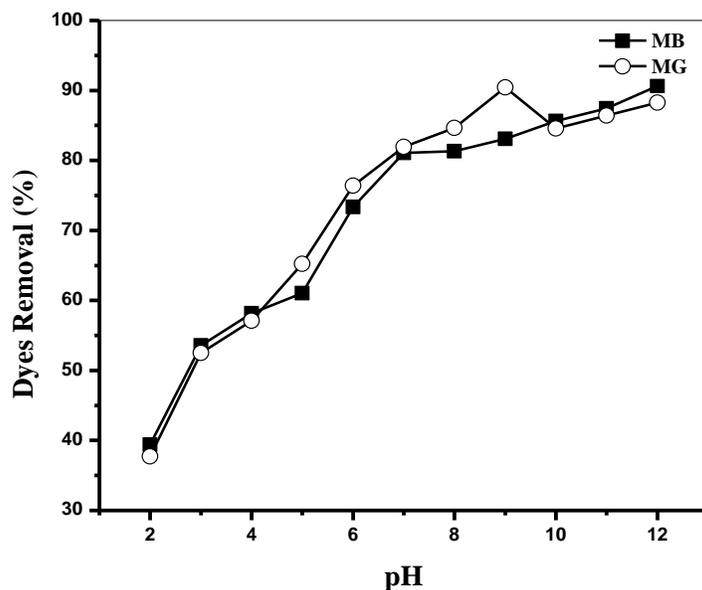


Figure 5 Effect of pH

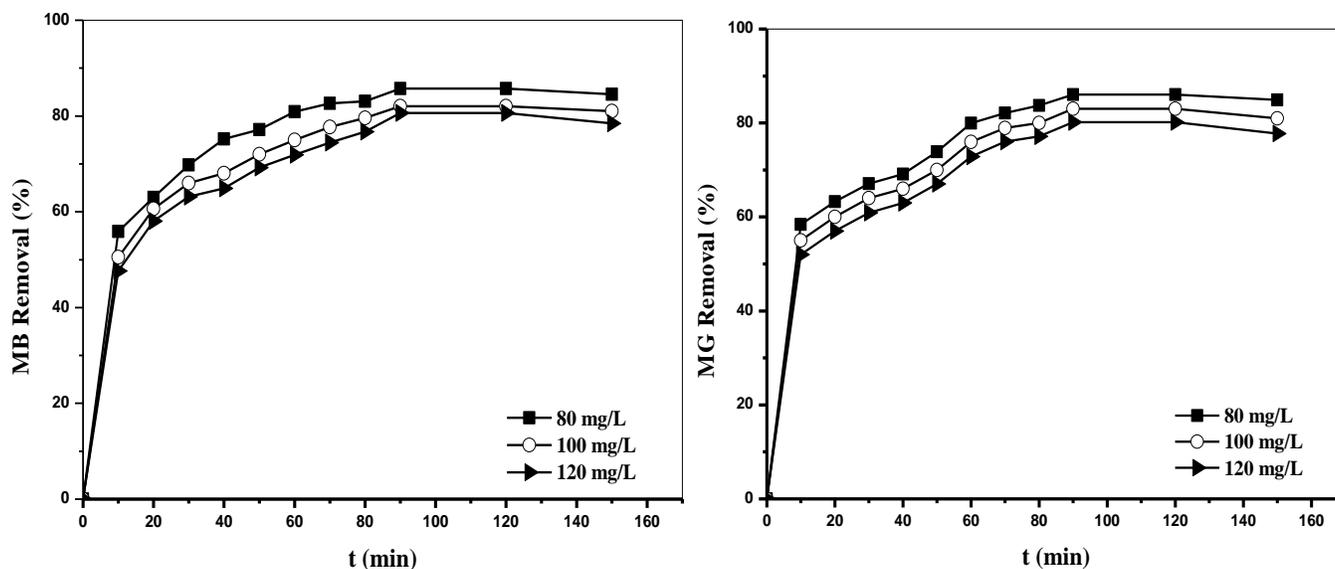


Figure 6 Effect of Contact time

Effect of contact time and initial dyes concentration

Figure 6 shows the evolution of the adsorption rate of MB and MG as function of contact time at different initial dyes concentration (80 , 100 and 120 mg L^{-1}). The percentage removal of MB and MG removed by adsorption onto ECAC increased with increasing time, the adsorption process was initially fast (contact time < 60 min), and then slows, the equilibrium was established after approximately (≈ 80 minutes). The fast adsorption of MB and MG observed at the initial stage was probably due to the great concentration gradient between the dyes in solution and the dyes fixed in the adsorbent because of the available number of vacant sites at the beginning [14]. The progressive increase in adsorption and consequently, the attainment of equilibrium adsorption are initially due to the accumulation of MB and

MG molecules on the adsorption sites of the ECAC adsorbent as the contact time increase. However after a lapse of time of 100 min the remaining vacant sites are not easily occupied by the adsorbates [15] which results an appearing plateau due to the strong repulsive forces between the dye molecules on the used adsorbent [16]. According to the same results, a decrease in removal efficiency of dyes is observed as the initial dyes concentration increases. This is can be explained by a high initial dye concentration led to an increase of mass gradient between the solution and ECAC adsorbent, provided as the driving force for the transfer of dye ions from bulk solution to activated carbon surface [17].

Kinetic Study

Four kinetic models, pseudo-first-order, pseudo-second-order, Elovich and intra particle diffusion, were used to analyze the data obtained at different initial concentrations of MB and MG in order to understand the possible adsorption mechanism and the rate.

Pseudo first order and pseudo second order models

The pseudo first order (Equation 1) and the pseudo second order (Equation 2) models were most commonly used to determine the rate constants and to analyze the adsorption process. The linear forms of these kinetic models can be expressed as:

$$\log(q_e - q_t) = \log q_e - k_1 t / 2.303 \quad (1)$$

$$t/q_t = 1/k_2 q_e^2 + (1/q_e)t \quad (2)$$

Where q_e (mg/g) is the adsorption capacity at adsorption equilibrium, q_t (mg/g) is the adsorption capacity at adsorption time t (min), K_1 (1/min) and K_2 (g/mg.min) are the equilibrium rate constants of Pseudo-First-Order and Pseudo-Second-Order models, respectively.

Based on above Equations, the corresponding results are tabulated in the following **Table 3**, and the obtained plots for different initial MB and MG concentrations are shown in **Figure 7**.

Table 3 Pseudo-first order and Pseudo-second order constant and their correlation coefficients

Kintetic studies	Initial conc (mg ⁻¹)	Methylene Blue				Malachite Green			
		qe expt (mg ⁻¹)	qe calculated (mg ⁻¹)	k1/k2/ (min ⁻¹)	R ²	qe expt (mg ⁻¹)	qe calculated (mg ⁻¹)	k1 (min ⁻¹)	R ²
Pseudo first order	80	67.61	61.518	0.0299	0.917	68.82	79.250	0.0368	0.882
	100	81.97	70.469	0.0322	0.947	79.18	53.951	0.0322	0.903
	120	99.79	81.283	0.0322	0.952	89.25	41.400	0.0345	0.811
Pseudo second order	80	67.61	66.667	0.0006	0.999	68.82	71.429	0.0009	0.984
	100	81.97	83.333	0.0005	0.999	79.18	83.333	0.0010	0.998
	120	99.79	100.000	0.0005	0.999	89.25	90.909	0.0008	0.998

The correlation coefficients of pseudo-first-order (Table 3) are not higher for MB and MG adsorption even at high concentrations. The experimental q_e values are not in agreement with the calculated ones (Table 3), suggesting that the adsorption of MB and MG on ECAC does not fit well with first-order kinetics. However, the correlation coefficients for the pseudo-second-order kinetic model are much higher for all initial MB and MG concentrations, and the experimental q_e values are in good agreement with the pseudo second-order kinetic model (Table 3). This indicates that the rate-limiting step may be chemisorption, which involves valency covalent forces through electron-sharing between the hydrophilic sites of ECAC, and dyes cations [18]. A similar trend was also reported for the adsorption of cationic dyes on activated carbons [18-20], which the adsorption rate was determined by the free adsorption site on the surface of the adsorbent.

Elovich model

The Elovich model (Equation 3) was used to describe chemical adsorption mechanism of MB and MG onto ECAC, because it is based on a general second-order reaction mechanism for heterogeneous adsorption processes [21]. The Elovich equation is expressed in linear form as:

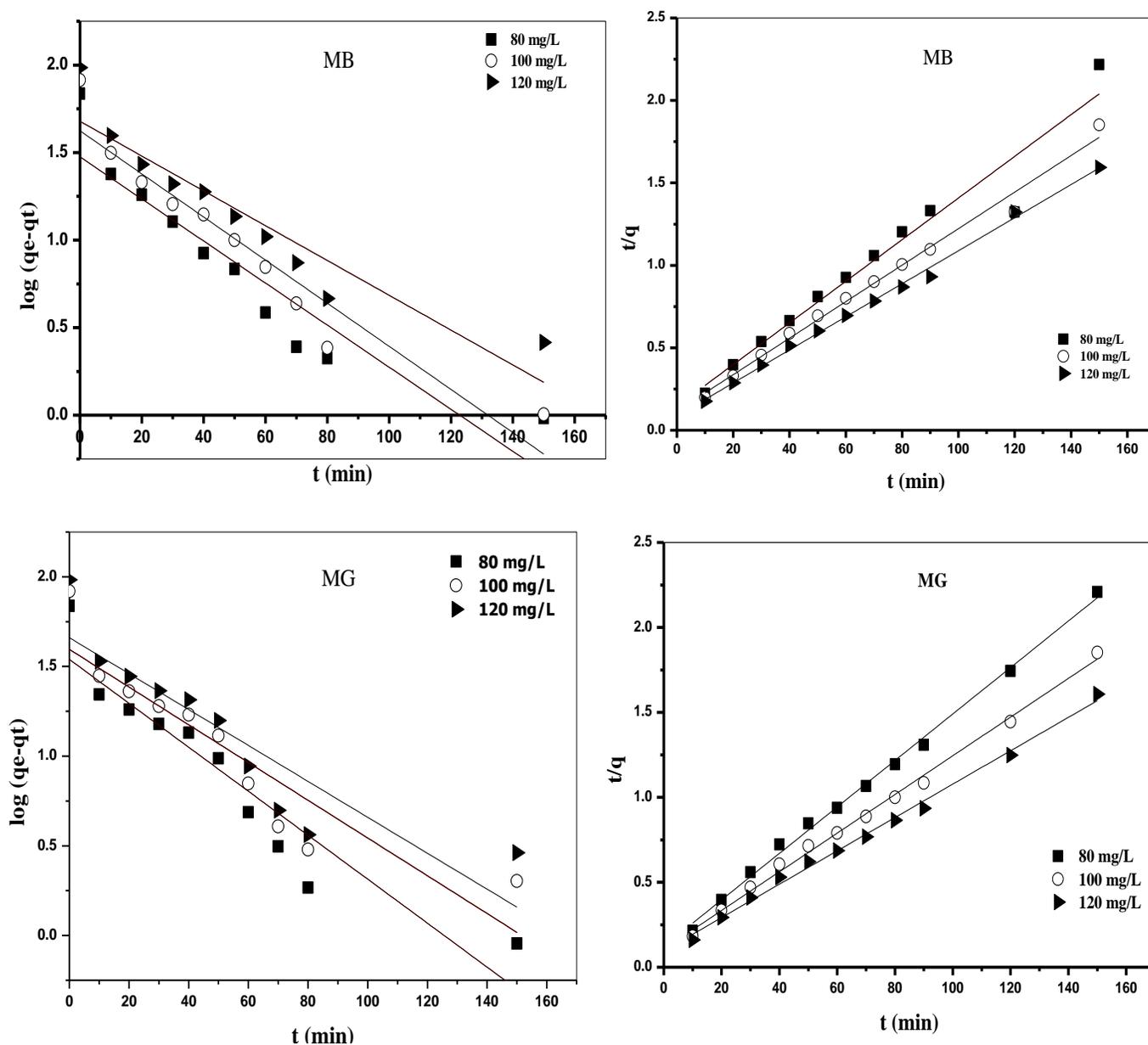


Figure 7 Pseudo first order and pseudo second order models of MB and MG

$$q_t = \frac{1}{\beta} \ln(\alpha\beta) + \frac{1}{\beta} \ln t \quad (3)$$

Where α ($mg/g \cdot min^2$) is the initial adsorption rate and β ($g/mg \cdot min$) is the desorption constant, which is related to the activation energy and the extent of surface coverage for chemisorption [21]. The experimental data in **Figure 8** were fitted linearly by using Equation 3 (qt vs. $\ln t$). The values of α , β , and R^2 are also listed in **Table 4**. From the obtained data, it can be seen that the Elovich model provides a comparable fit to the experimental data based on R^2 values for all MB and MG concentrations. This further indicates that the adsorption of MB and MG onto ECAC adsorbent is to be regarded as a “chemical” rather than a “physical” process, which further highlights the importance of the surface functional groups of the activated Eichhornia Crassipes carbon. Moreover, it was also observed that the calculated constants β are the lowest benefitted to the formation of chemical bonds between dyes molecules and active groups of used activated carbon.

Intraparticle-diffusion

The adsorption mechanism of adsorbate onto adsorbent follows several steps: film diffusion, pore diffusion, surface diffusion and adsorption on pore surface [2, 22]. The slowest of these steps controls the overall rate of the process. The intra-particle diffusion equation is expressed as:

$$q_t = k_i t^{1/2} + C_i \quad (4)$$

Where q_t (mg/g) is the fraction dye uptake at time t , k_i (mg/g.min^{0.5}) is the intra-particle diffusion constant, and C_i (mg/g) is a constant that gives an idea about the thickness of boundary layer. If $C=0$, the intra-particle diffusion is the only rate-limiting step, conversely if $C \neq 0$, the adsorption process is controlled by various adsorption mechanisms [14]. The plot of q_t vs. $t^{0.5}$ for all MB and MG concentrations is shown in **Figure 9** and the obtained parameters are listed in **Table 5**. From the obtained data, it can be observed that the constant C is not zero in any case, which suggests that pore diffusion was not the rate limiting step. So, the MB and MG adsorption process may be of a complex nature consisting of both; surface adsorption and intra-particle diffusion [9]. It showed also that the K_{id} values increase with increasing MB and MG concentrations results in an increase in the driving force, which is an indication of the increase of the thickness of the boundary layer [14].

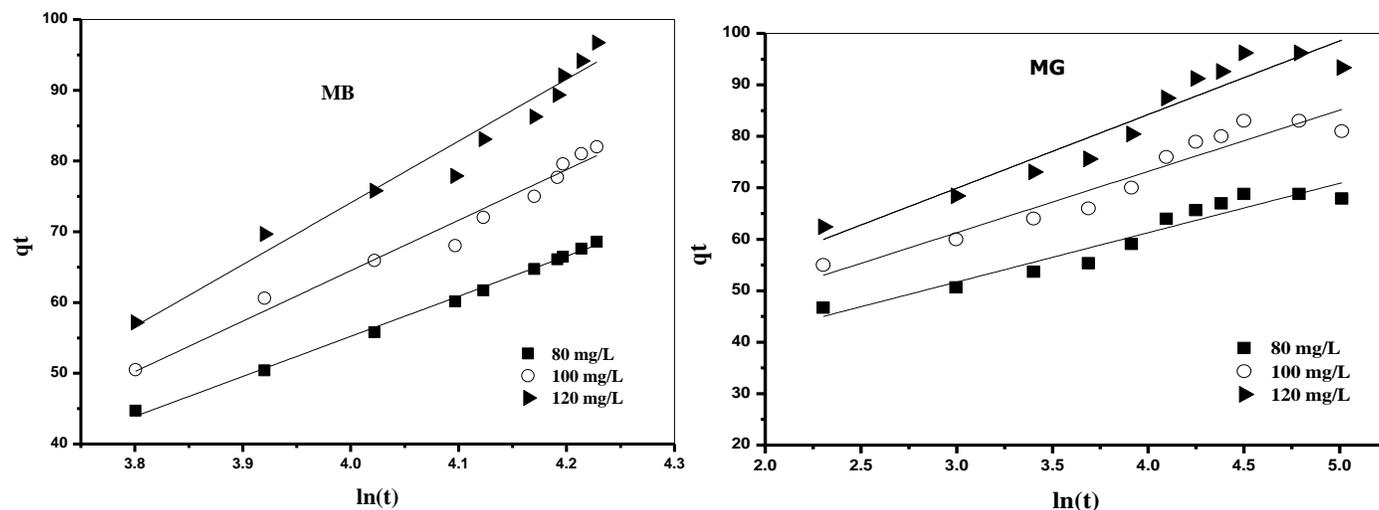


Figure 8 Elovich Kinetics models of MB and MG

Table 4 Elovich Kinetic Parameters

Initial Concentration mg/l	Methylene Blue			Malachite Green		
	α mg/g/min	β mg/g	R^2	α mg/g/min	β mg/g	R^2
80	2.748	0.017	0.998	104.64	0.104	0.962
100	3.226	0.014	0.987	101.84	0.844	0.960
120	3.734	0.011	0.981	94.268	0.069	0.958

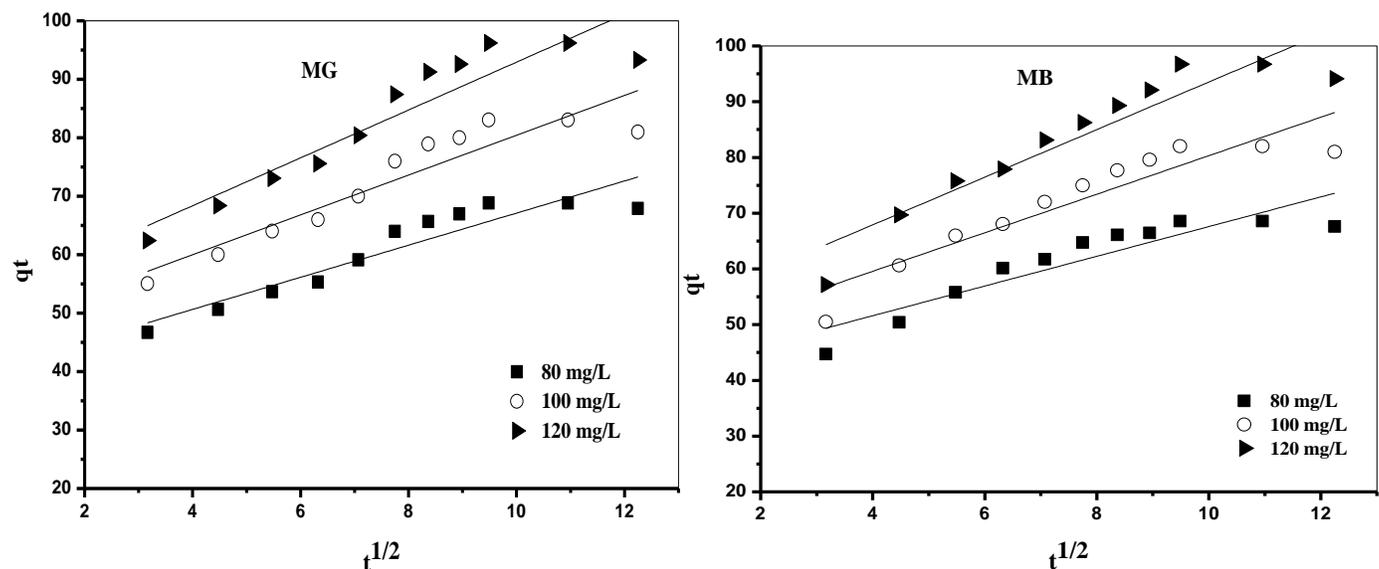


Figure 9 Intraparticle-diffusion models of MB and MG

Table 5 Intra Particle Diffusion Parameters

Initial Concentration mg/l	Methylene Blue			Malachite Green		
	K _{id}	C _i	R ²	K _{id}	C _i	R ²
80	2.666	40.93	0.916	2,745	39.65	0.940
100	3.456	45.74	0.933	3.407	46.35	0.937
120	4.271	50.81	0.936	4.093	51.99	0.935

Adsorption isotherms

Adsorption isotherm is used to describe adsorbent–adsorbate interaction and the equilibrium distribution of adsorbate molecules at the solid–liquid phases [23]. The adsorption equilibrium of MB and MG was evaluated using Langmuir Freundlich and Temkin models.

The Langmuir isotherm theory (Equation 5) assumes that the adsorption is monolayer onto identical active sites of adsorbent with uniform adsorption energies and without lateral interaction and steric hindrance between the adsorbed molecules [24]. It can be expressed in the linear form as:

$$\frac{C_e}{q_e} = \frac{1}{Q_o b} + \frac{C_e}{Q_o} \quad (5)$$

Where C_e (mg/L) is the equilibrium concentration of MB, q_e (mg/g) and q_{max} (mg/g) the equilibrium and maximum adsorption capacities, respectively, and K_L is the Langmuir equilibrium constant.

The Freundlich isotherm model (Equation 6) assumes that the adsorption is multi-layered and that the adsorption on surface is non-ideal and reversible, which is not restricted to the formation of monolayer coverage [24]. It can be expressed in the linear form as:

$$\log q_e = \log k + \left(\frac{1}{n}\right) \log C_e \quad (6)$$

Where, K_F (L·g⁻¹) is the adsorption coefficient, $1/n$ is a constant related to the surface heterogeneity, and q_e (mg/g) and C_e (mg/L) are the equilibrium adsorption capacity and the equilibrium MB concentration, respectively.

Temkin model, considers the effects of heat of adsorption and the adsorbent-adsorbate interaction on adsorption isotherms [24]. Its linear form can be expressed as:

$$q_e = \beta \ln k_T + \beta \ln C_e \left[\text{where, } \beta = \frac{RT}{b} \right] \quad (7)$$

Where K_T (L/mg) and b (J/mol) are the isotherm constant and Temkin–Pyzhev constant, respectively.

The theoretical parameters obtained from **Figure 10** are listed in **Table 6**. According to the obtained data, Freundlich model fits better for the MB adsorption as its correlation coefficient value was higher and closer to the unity ($R^2 = 0.997$) compared with that from Langmuir and Temkin models. For the adsorption of MG onto used activated carbon, the both Freundlich and Temkin models showed a good correlation coefficient with the experimental data ($R^2=0.999$) as compared with the Langmuir one. However, according to the residual sum of squares RSS of each obtained regression, which is the measure of the discrepancy between the data and the estimation model, it's clear that the obtained regression by Freundlich model provide the small RSS as compared to the Temkin regression indicating a tight fit of Freundlich model to the MG adsorption data. These finding confirms that the adsorption of MB and MG onto the used activated carbon occurs in multilayer and the ECAC surface has heterogeneous sorption sites. Q_m was an important Langmuir constant, representing the maximum capacity of used ECAC at equilibrium was calculated as 127.38 mg/g for MB and 165.28 mg/g for MG. A comparison of maximum adsorption capacities of the activated carbon prepared in this study with other reported values for some others carbons is listed in **Table 7**. It shows that ECAC has a comparable adsorption capacity with the adsorbents reported in the literature, revealing its suitability to remove cationic dyes from aqueous solutions.

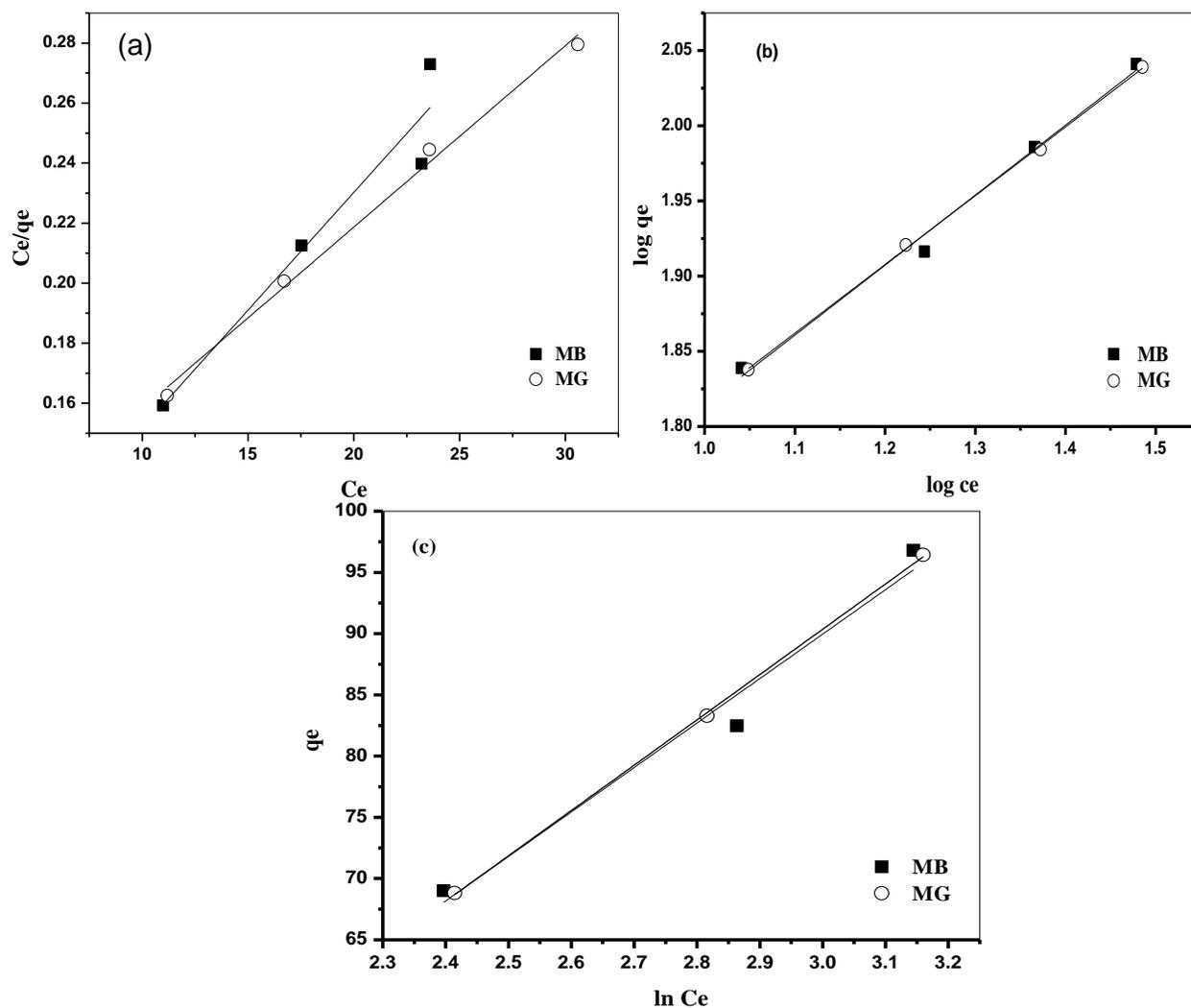


Figure 10 Adsorption isotherms: (a) Langmuir isotherm, (b) Freundlich isotherm, (c) Temkin isotherm

Table 6 Adsorption Isotherm Parameters

Isotherms	Parameter	MB	MG
Langmuir	$q_{max} (mg.g^{-1})$	127.38	165.28
	$K_L (L.mg^{-1})$	$499 E^{-4}$	$631E^{-4}$
	R^2	0.966	0.992
	RSS	$4.51E^{-4}$	$3.90E^{-5}$
Freundlich	$1/n$	0.465	0.457
	KF	3.852	3.894
	R^2	0.996	0.999
	RSS	$1.79E^{-4}$	$1.21E^{-5}$
Temkin	$K_T(L/mg)$	18.18	19.56
	β	0.465	0.457
	R^2	0.987	0.999
	RSS	9.849	0.110

Table 7 Comparison of maximum adsorption capacities of various activated carbons for cationic dyes removal

Activated carbon adsorbent	$q_{max}(mg.g^{-1})$	References
Olive stone activated carbon	16.12	[2]
Activated carbon-clay	178.64	[25]
Mesoporous activated coconut shell	200	[22]
Activated carbon of walnut wood	18.51	[26]
Eichhornia crassipes activated carbon	127.38 & 165.28	This study

Desorption Studies

Spent activated carbon (SAC) disposal at a landfill creates soil pollution, so they needed to be regenerated and reused. Repetitive usage of regenerated and reused SAC provides economic profit. Chemical regeneration method was one of the more apt and inexpensive technique. In this study, SAC was regenerated using sodium hydroxide (NaOH) solution. The effectiveness of NaOH in regeneration of SAC was tabulated. The regeneration performance for SAC was calculated via the equation 8 [27]

$$RE\% = \frac{A_r}{A_0} \times 100 \quad (8)$$

Where A_0 is original adsorption capacity and A_r is adsorption capacity of the regenerated ECAC

The regeneration efficiency of regenerated SAC was as good as to fresh activated carbon with regeneration efficiency more than 90% in iodine adsorption test and 95% in MB adsorption test is listed in **Table 8**.

Table 8 Regeneration Efficiency Parameters of SAC

Sample	Regeneration methods	Regeneration efficiency (%)	Yield (%)	Particle size degradation (%) after 5 cycles of operation
SAC1	Alkali treatment (NaOH)	93.8%	95	0.33

Use of Desorbed Carbon

The raw materials used in the production of cement are finite and non-renewable and need to be conserved for future generations. To attain sustainable construction a strong trend favoring the increased use of admixture in concrete is emerging throughout the world. In this study the desorbed carbon (DC) is used as admixture. Replacement made for 0%, 1%, 2%, 3% and 4%. High % replacement of 4 % was considered. The Physical properties and compression strength test of material were tested and results are given in the **Table 9**.

Table 9 Physical properties and ultimate strength of the Specimen.

Testing material: Bharathi cement – OPC53 Grade + 4% DC

S. No.	Test	Results	IS code values as per IS12269:2013
1	Fineness Test	3.2 %	Not more than 10%
2	Soundness	0.5 mm	10 mm
3	Consistency	27 %	---
4	Initial Setting Time	35 mins	30 mins
5	Final Setting Time	630 mins	600 mins
6	Compression Strength Test (Average of 5 Cubes)	24.26 N/mm ² (3 days) 35.81 N/mm ² (7 days) 51.92 N/mm ² (14 days)	27 N/mm ² 37 N/mm ² 53 N/mm ²

The result showed that 4 % replacement of DC in concrete is economic and safe to use in construction to sustain its better quality.

Conclusion

- Adsorption of MB and MG dyes increased with contact time, temperature, adsorbent dose and pH.
- pH_{zpc} of the adsorbent was found to be 7 and 9 for MB and MG respectively.
- A maximum of 90% colour was removed at pH-12 but pH-7 was optimized, so that discarded colour removed solution can be reused for vehicles cleaning and washing purposes.
- The values of $R^2 < 1$ (Hall constant), obtained in this study was highly favorable to Freundlich adsorption isotherm indicated that the adsorption of MB and MG dyes on ECAC were chemisorption.
- Adsorption of MB and MG dyes on the adsorbent was fitted more appropriately by pseudo second order kinetic model it was evidenced by q_e and R^2 values.
- Intraparticle diffusion constant (K_{id}), adsorption capacity (K_f) and monolayer concentration (X_m) increase with the increase in temperature revealed that adsorption of MB and MG on ECAC is endothermic

- Charcoal prepared from waste materials, *Eichhornia Crassipes* (EC) was found to be cost effective in removing MB and MG dyes from aqueous solutions without leaving any secondary pollutant.
- Desorbed carbon was effectively regenerated, recovered and reused which renders that this decolourisation method was more economical, valuable and important.
- It is hoped that these studies can be extended further for the removal of colored effluents of dyeing and processing industries.

Reference

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