COMPARATIVE REMOVAL OF THREE TEXTILE DYES FROM AQUEOUS SOLUTIONS BY ADSORPTION : AS A MODEL (CORN-COB SOURCE WASTE) OF PLANTS ROLE IN ENVIRONMENTAL ENHANCEMENT

Aseel M. Aljeboree* and Ayad F. Alkaim

Chemistry Department, College of science for women, University of Babylon, Iraq.

Abstract

In this work, the activated carbon (*corn-cob source*) preparation from *corn-cob source* utilizing the operation of activating H2SO4, a frugal items, display Showed acceptable behavior in eliminating oxygen through absorption Methylene Blue (MB), crystal violet (CV) Maxilone blue (GRL) of an aqueous solution. The adsorbent was characterized with (FT-IR), and (SEM). The adsorption studies were done to estimate the influence of primary concentration (10-100 mg L^{-1}), pH (2–10), mass (0.02–2 g) and influence of heat (16-45 0C). It discovered pH has main part in adsorption operation ; adsorption ability was effected by the adsorption capacity of the physical characteristics and surface chemicals carbon and pH of the solution. The experimental information was analyzed by three various kinds of isotherm samples, the Langmuir Isotherm, the Freundlich Isotherm and Temkin Isotherm at a various temperatures. The experimental outcomes are well fitted with homogeneous Freundlich and Tempkin isotherm, which in turn refers to a multi-layer dye adsorption. The change in energy free of Gibbs (ΔG), entropy (ΔS), and The inherent inner energy (ΔH) was calculated from absorption results that found that the absorption process was heat absorbent.

Key words : Textile dyes, Plant; Adsorption, corn-cob source.

Introduction

Numerous of remarkable industries, like texture, animal feed, paper, leather, cosmetics. Use of dyes for coloring finished products (Prahas 2008), and Thus producing big quantities of liquid wastes consisting of dye. Existence of water-consisting of pigment can be negatively influence the water environment by blocking light penetration, which prevents photosynthesis of aquatic plants (Abbas 2016; Aljeboree 2015) So, water pollution becomes one of the most dangerous ecological issues, therefore remediation and disposal of sewage has aroused diffused concern. It is believed that adsorption mechanism is one of the most effective way to eliminate contaminants from aqueous solutions, because it is simple, appropriate, and low price with high efficiency absorption and The ability to adapt to a wide. Different adsorbents agents were used to remove dyes from aqueous solutions (Hari *et al.* 2005). Activated Carbon (AC), like an important

class of nanomaterial's, has received increasing attention in last years (Aseel M. Aljeboree 2018). AC largely used in all types of products due because of its unusual electrical, chemical, and physical features So, activated carbon (AC) become one of the adsorbents utilized in eliminate dyes from liquid waste (Mahmoud, 2012.). Activated Carbon, also called Activated Charcoal, Activated Coal, or Carob Activates, way of carbon operation has little amounts pores which increases space available of absorption or chemical reactions. 16 Activation occasionally replaced with activity. Because active to a very small degree, only one gram of activated carbon has a surface area in excess of 500m², as determined by gas absorption. Enough phase of stimulation can be achieved valuable application only from high surface area; yet, the chemotherapy often promotes absorption characteristics (Ayad Fadhil Alkaim 2015). In this research, activated carbon as a model for plant using were utilized to study the elimination/adsorption Methylene Blue (MB), crystal violet (CV) Maxilone blue (GRL) from

an aqueous solution. Influence of different operating standards, like the activated carbon block, temperature, and concentration of the dye, were studied and influenced. Thermodynamic calculations of adsorption operation needed understand the absorption techniques, spontaneity, and temperature adsorption utilizing various thermodynamic standards, it was also isothermal adsorption assessment and reporting.

Materials and Methods

Preparation of H_2SO_4-activated carbon (corn-cob source)

corn-cob source are get it from local Iraqi Markets and utilized like precursors. Primarily, washed with filtered to eliminate impurities stuck, desiccating 110^0C for 24 h then sifting so as utilize molecules size ranging from 1 mm 2mm. H_2SO_4-activated carbon model (*corn-cob source*) prepared in two stages: Carbonate the dried material at 50^0C for 2 h lack of air utilizing furnaces (600 *· 40 mm) at an average of 10 C/ min up to 500 C. model cold and submerged by specific metering of H_2SO_4 (20 g of the model charred with 60 g of H_2SO_4 (50%)) in 100 ml filtered for 24 h the heat of the room, desiccating 110 C ultimately stimulation 600 C for 4 h. The model washing repeatedly by filtered water until neutral filtration dried at 110 C a fixed metering eventually stocked in a clean dry bottle.

Features of preparation H_2SO_4-activated carbon (CSAC)

Spectrums infrared were get it utilizing spectrum infrared Fourier transform (FTIR-2000, PerkinElmer). FT-IR, fine-grained material was finely mixed with KBr (Merck) by 1:100 for transparent granules. FT-IR Functional group spectra assured adsorbents. External morphology of activated carbon molecules illustrated utilizing electronic scanning microscopy (JEOL-JSM-6380 LA, Japan). Carbon molecules installed model seed plated by chips utilizing gold plating machine (JEOL-JSM-420, Japan). Model illustrated spontaneously in computer programs.

Influence of various standards of adsorption operations of GRL, MB and CV on corn-cob source.

Influence of primary dye concentration

Primary experiment of dye concentration 10, 20, 30, 50, 75, and 80 mg/L of three various dyes pH, heat, partial size, and mass dose.

Influence of pH

Influence of pH on average elimination color illustrated in pH term 2, 4, 6, 8 and 10 at 30^0C, 120 rpm,

0.1 g of *corn-cob source* (P.S 50 nm) and 100 mL dye concentration tincture (10–80) mg/L. pH modified utilizing 0.1 N NaOH 0.1 N HCl sol applying Orion 920A pH-module united pH pole. pH- module combined with NBS stores before each measurement.

Influence of temperature

Influence of temperature adsorption ability *corn-cob source* performed 18, 30, 45 C in fixed heat restroom in normal solution pH 6, 120 rpm 0.1 g *corn-cob source* (P.S 50 nm) and 100 mL dye concentration (10–80) mg/ L.

Influence of mass dose

Influence of mass dose investigated by stirring in different (0.02, 0.025, 0.072,0.1, 0.15 and 0.2 g) of *corn-cob source* 30^0C, 120 rpm, (P.S 50 nm) 100 mL of (CV or MB or GRL) dye concentration (10–100) mg/L.

## Results and Discussion

FT-IR Analysis

Corn-cob source fundamentally consists from lignin, cellulose, hemicelluloses and plenty collections of hydroxyl like tannins. Whole ingredients are energetic ion exchange vehicles. Lignin, third main ingredient of the wooden cell wall formed from phenyl propane kernel; odorous circles of three a series of three carbon sides immediately obtainable from react of cationic GRL, MB, CV ions (Prahas 2008). FTIR spectra for Fugs *corn-cob source* t of normal formula and laden GRL, MB, CV dyes illustrated by fig. 1. *Corn-cob source*, there is sturdy summit 3445 cm^{-1} symbolized –OH Phenolic group growing from cellulose and lignin, climax 2927 cm^{-1} reference existence –CH_2 extension of aliphatic complex. FTIR spectrum GRL MB, CV Fully loaded, illustrated by fIg. 1 (Cazetta 2011), That the peaks resulting from functional collections lightly influenced by location and density. Reference that adsorption GRL, MB, CV dyes on roof of corn-cob source maybe by complexity or materialistic, that could be weak interaction and the forces of Van der Waals electrostatic. In spite of, there is no chemical correlation in the process and therefore, FTIR roof cracks remains unaltered.

Scanning electron microscopy (SEM)

Electronic scanning microscopy (SEM) was an essential instrument for described externally formed shape and fundamental physical features of capacitor. SEM adsorbent items taken by Adsorption dye corn-cob source (Fig. 2). Obviously there is a good probability of coloring in pores. SEM mixed samples appear extremely characteristic black spots that could be a sign of the active adsorption of pigment particles in sinus and pores of
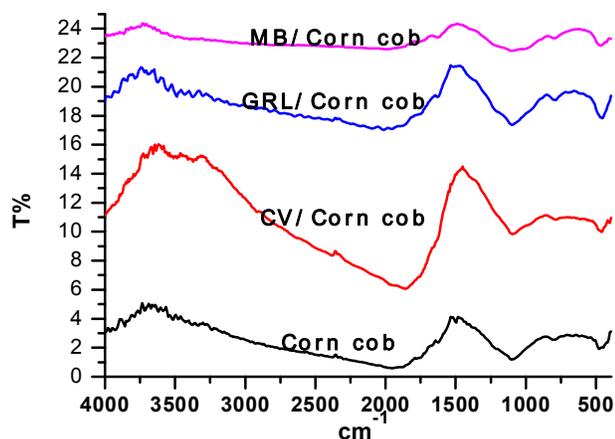
Fig. 1: FT-IR spectrum of *corn-cob source* before(a), after(b) MB (c) CV (d) GRL adsorption (adsorbent dosage = 0.1 g, heat = 30^{0}C, Vibration average = 120 rpm and pH = 6.4, and connect time 24 hr).
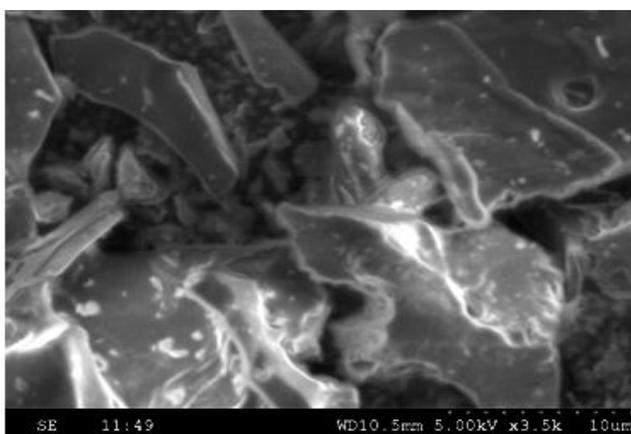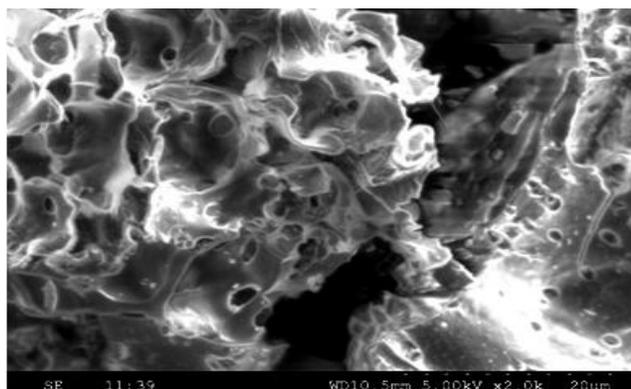
Fig. 2: SEM Images of activated carbon (*corn-cob source*).

adsorbent (Sheel and Kadim, 2012). Photomicrograph illustrated clearly by (Fig. 2) dye loading coated pipette by pigment particles on entire exterior at normal pH states. Dye molecules created film free of vacuum that hides particle engravings and porous porosity.

Effect of mass dosage

One of the standards which substantially influence

sorption ability is amount of absorbent material in the liquid stage because it defines adsorbent ability of a particular primary condensation of dye solution (Hayati, 2012) influence of corn-cob doses on amount of dye absorbed by contact with 100 ml dye solution with primary dye concentration of 50 mg/L adsorbent, a connection time 24 h heat 30^{0}C, vibration speed 120 rpm, perfect pH of 6.2. Various amounts of adsorbents (0.02, 0.03, 0.05, 0.075, 0.1, 0.15, and 0.2 gm) gathered. After balance state, models permitted stabilize for some time after which the floating solution gathered, centrifuged and tested. Outcomes illustrated in fig. 3. Rising rate of dye elimination with rising of adsorbent dose. for example, rising 45.1 to 95.5% noticed while dose rising 0.02 to 0.2 g of dye GRL and For instance, an increase 25 to 55.5% noticed while dose rising 0.02 to 0.2 g of the dye MB for example, rising 10.1 to 27.5% noticed while dose rising 0.02 to 0.2g of the dye CV Shows in Fig. 3 Low absorption ability with rising dose of adsorbent at Continuous dye concentration and size probably imputed to saturation of adsorption locations because of particulate reaction like combination (Saeed, 2010 and Aseel, 2015) rising in rate of dye elimination with adsorbent dosage probably imputed to rising in Surface area adsorbent, increased adsorption locations obtainable for adsorption, as already mentioned (Aksakal, 2010)

Influence of solution pH on dye adsorption

The pH a great control standard in adsorption operation. Not only effect the degree of ionization for adsorbate but also surface of adsorbent present in the solution Influence pH on adsorption elaborate utilizing 50 mg/L dye concentration, pH 2–10 at 30^{0}C, outcomes illustrated in fig. 4. dye absorption (qe) , E% found to rise with rising pH. Low adsorption MB, CV acidity pH possibly because excessive existence H+ ions contending with positive sets on dye of adsorption locations (Chakraborty, 2011) at top pH, surface of corn-cob source may acquire negatively charged, that reinforce dye ions positively charged during electrostatic attraction forces (Chakraborty, 2011; Aljeboree, 2015). Illustrated final adsorption GRL gained from neuter pH 7 While less adsorption achieved pH3. pH solution rising, adsorption of dye GRL lessening; because deactivation of the positive hydrogen ions that way strengthen the activities of electricity collisions between negative charges of dye and corn-cob source surface (Auta 2011). While neuter pH, functional sets of activated carbon become protonated, that fundamentally Carboxylic groups (COOH^{+2}), Phenolic (OH^{+2}) and Chromenic group (Al-Degs, 2008) pH 10, surface of corn-cob source becomes more positively charged, which strengthen (GRL) adsorption
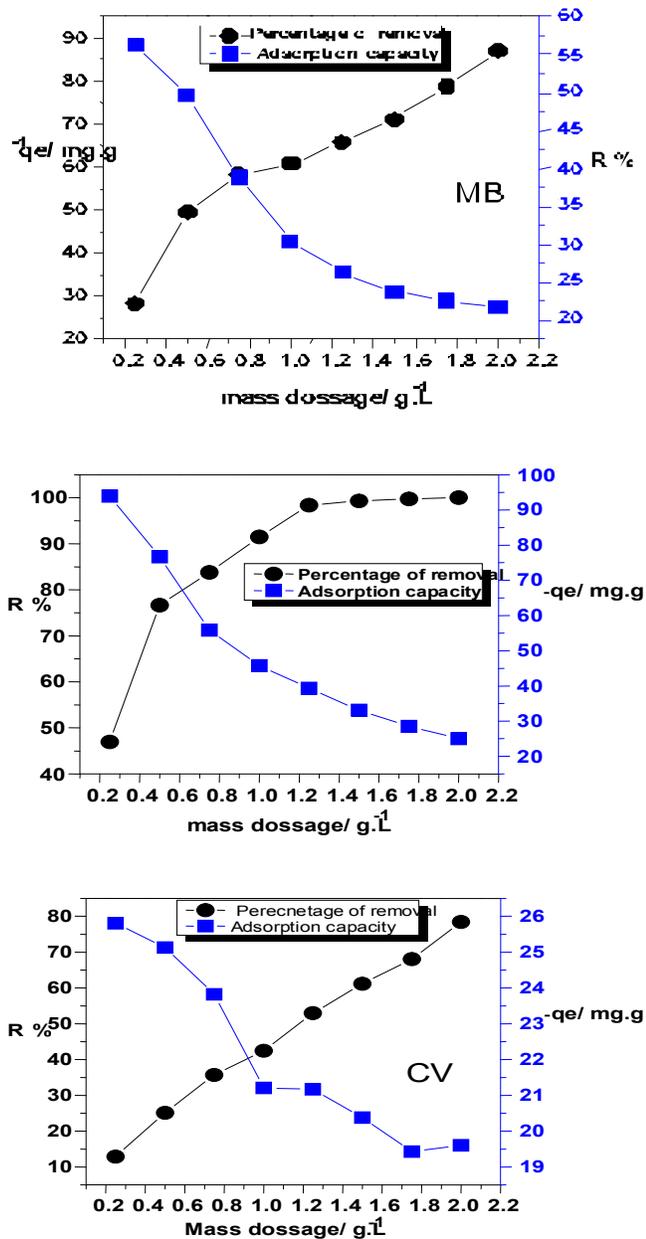
Fig. 3: Effect of mass *corn-cob source* (a) GRL (b) MB and (c) CV adsorption (adsorbent dosage = 0.1g, T = 30°C, Vibration average = 120 rpm and pH = 6.4, and connect time 24 hr).

during electromagnetism.

Adsorption isotherms

Equal balance absorption essential significance in the design of adsorption method for practical applications, Isotherms possibility utilizing for explaining particular relationship between concentration of adsorbate and its range of on adsorbent surface at fixed heat (AM, 2016). Adsorption information most widespread illustrated by balance isotherm value, it is a piece of quantity of absorbate eliminated per unit sorbent (qe) like solid state concentration of absorb ate in the liquid state (Ce) various
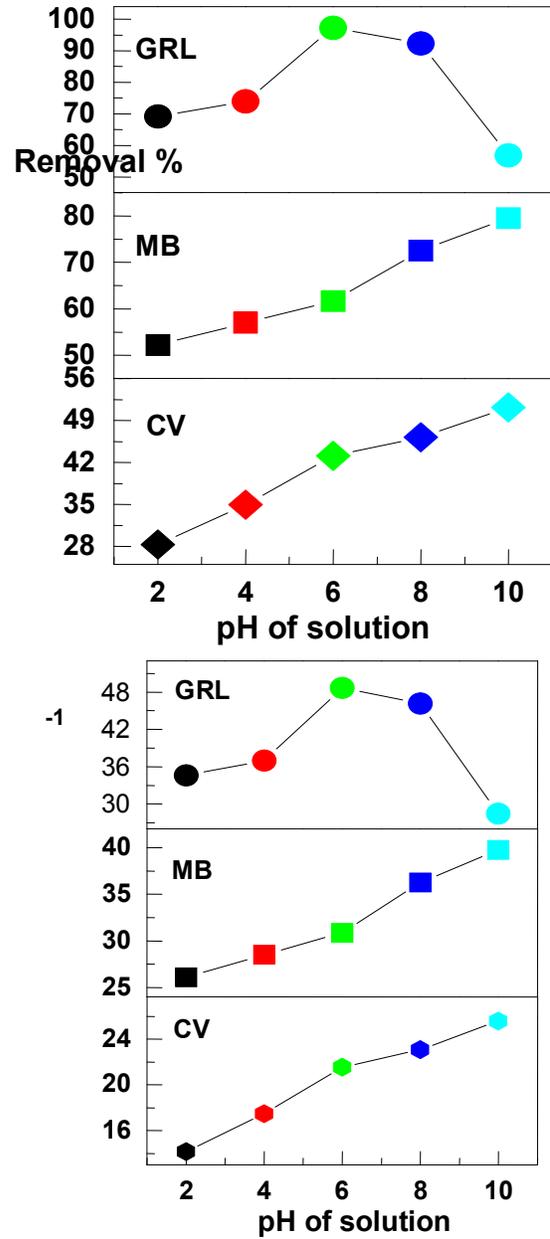
Effect of solution pH on the adsorption of MB ,CV,GRLdyes on corn cob **Exp. Conditions: T=303, C0=50mg/L, adsorbent conc.=1.0g.L-1, contact time 24 h, agitation speed=120 rpm.**

Fig. 4: Effect of pH on the adsorption of three dyes (a) GRL (c) MB (d) CV adsorption (adsorbent dosage = 0.1 g, T = 30 °C, Vibration average 100 rpm, and connect time 24 hr).

Isotherm samples utilizing to predict reality of experiencial information. In this research, three of essential significance utilized samples, Langmuir, Freundlich and Langmuir- Freundlich Isotherms utilized to characterize adsorption balance. Non-linear shape of Langmuir Isotherm sample (Langmuir 1916) specific like –

$$q_e = q_{max} K_L C_e / 1 + K_L C_e \qquad (1)$$

K_L (L/mg) Langmuir adsorption fixed linked to power of adsorption, q_{max} and q_e (mg/g) are extreme and

Table 1: Parameters for defferent parameters isotherms for the adsorption of MB, GRL and Cv dyes onto corn cob activated carbons at defferent temperatures.

Isotherms	Isotherm Parameters	290 K			303 K			318 K		
		MB	CV	GRL	MB	CV	GRL	MB	CV	GRL
Langmuir	q_m (mg.g^{-1})	37.670 ±1.969	27.815 ±2.091	65.583 ±3.372	35.784 ±2.012	32.887 ±0.077	74.246 ±3.749	41.940 ±1.564	33.864 ±0.340	86.889 ±5.782
	K_L(L.mg^{-1})	0.076 ±0.013	0.049 ±0.011	1.330 ±0.356	0.575 ±0.239	1.935 ±0.015	2.919 ±0.729	0.513 ±0.120	1.339 ±0.084	2.963 ±0.848
	R^2	0.9461	0.9145	0.8966	0.7084	0.9196	0.9128	0.8985	0.86362	0.8951
Freundlich	K_F	7.590 ±0.411	4.260 ±0.313	36.158 ±1.658	17.315 ±0.561	6.957 ±0.415	45.846 ±2.145	20.459 ±0.994	15.251 ±0.295	55.258 ±2.127
	$1/n$	0.348 ±0.014	0.386 ±0.019	0.191 ±0.017	0.192 ±0.009	0.336 ±0.015	0.185 ±0.019	0.188 ±0.014	0.196 ±0.005	0.215 ±0.020
	R^2	0.9901	0.9861	0.9605	0.9870	0.9872	0.9435	0.9676	0.9954	0.9549
Temkin	b/J.mole^{-1}	7.855 ±0.444	5.096 ±0.401	8.724 ±0.423	5.096 ±0.401	6.767 ±0.466	5.076 ±0.181	6.052 ±0.233	9.719 ±0.494	11.300 ±0.939
	K_T	0.871 ±0.159	24.240 ±11.763	75.290 ±21.389	24.240± 11.763	0.924± 0.215	12.630 ±2.558	21.381± 4.807	153.247 ±45.261	200.383 ±89.406
	R^2	0.9908	0.9810	0.9904	0.9863	0.9875	0.9974	0.9962	0.9883	0.9672

Table 2: Themodynamic functions ΔG, ΔH and ΔS of cv, MB and Gl absore on the corn cob.

| T/K	K_d	ΔG^0/ kJ.mol^{-1}	ΔH^0/kJ.mol^{-1}	ΔS^0/ J.K^{-1}.mol^{-1}
Corn-cob adsorbent/ CV adsorbate				
290	336.692	-14.030		
303	443.731	-15.354	12.230	90.720
318	526.798	-16.568		
Corn-cob adsorbent/ MB adsorbate				
290	556.751	-15.243		
303	652.551	-16.326	7.607	78.860
318	735.335	-17.450		
Corn-cob adsorbent/ GRL adsorbate				
290	5792.777	-20.890		
303	6563.199	-22.141	7.430	97.635
318	7597.592	-23.624		

Absorption ability balance, successively. Langmuir fixed produced from adsorption information range qe contra Ce (Fig. 5) illustrated Fig. 5. Freundlich Isotherm is based on hypothesis that adsorption found on unusual heterogeneous surfaces locations with various power of adsorption and Misfit. Non-linear shape of Freundlich Isotherm utilized check adsorption operation cohesion sample (Langmuir 1916).

$$qe = K_f C_e^{\ 1/n} \qquad \qquad ... (2)$$

K_f probably known like adsorption or apportionment factor and symbolized quantity of dye adsorbent for condensation balance unit. 1/n Heterogeneity element and n scale deviation from linear of adsorption. Rate repents grade of non-linear between sol condensation and adsorption like following : if amount similar to unit, adsorption is linear; if amount under to unit, means that
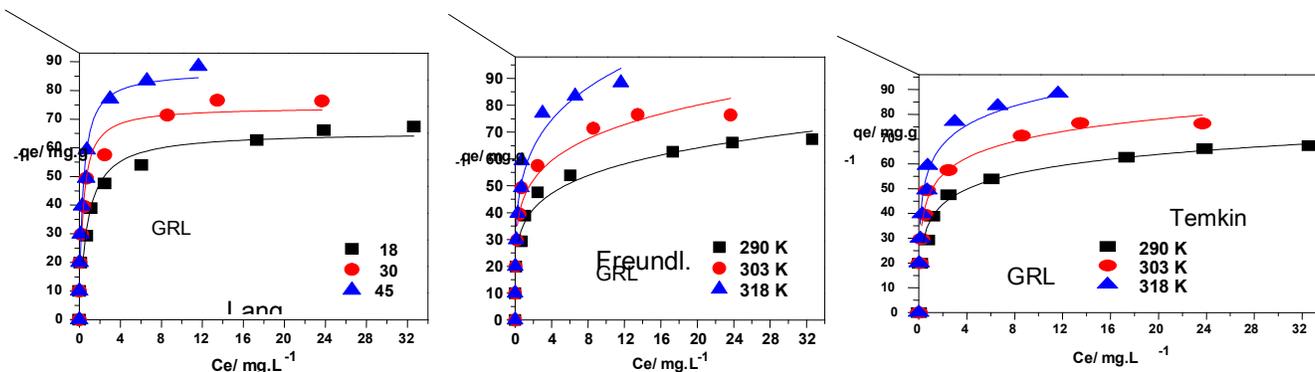
isotherm model plot of GRL adsorbed by corn cob at different temperatures. Exp.Conditions:, adsorbent conc.=1.0 g.L-1, contact time 24 h, agitation speed=120 rpm, pH 6.
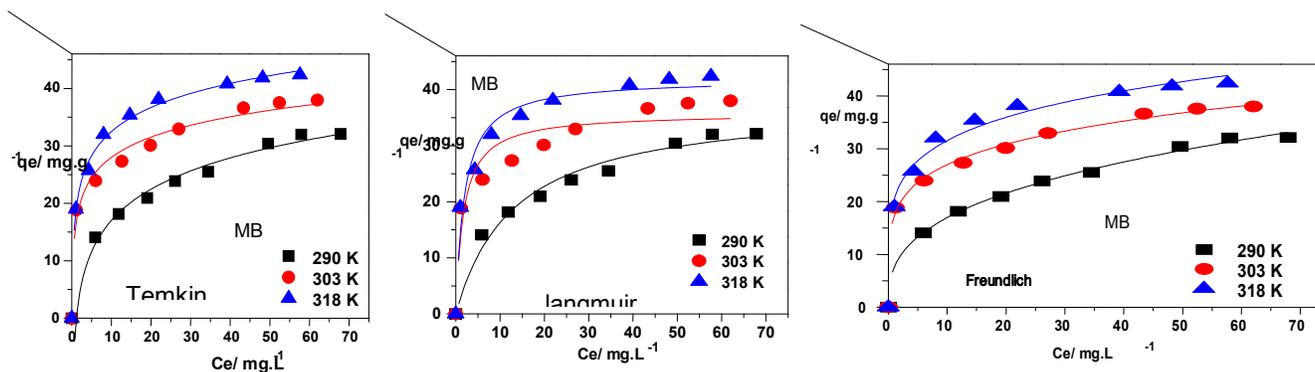
isotherm model plot of MB adsorbed by corn cob at different temperatures. Exp.Conditions:, adsorbent conc.=1.0 g.L-1, contact time 24 h, agitation speed=120 rpm, pH 6.
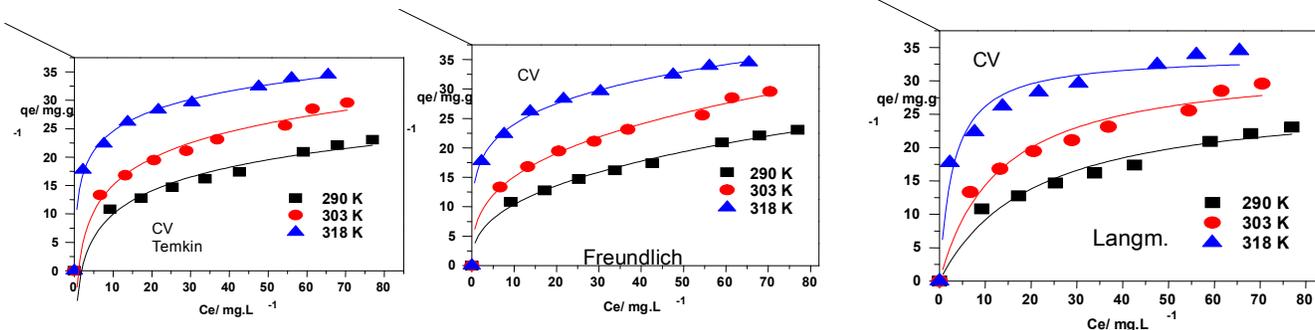
isotherm model plot of CV adsorbed by corn cob at different temperatures. Exp.Conditions:, adsorbent conc.=1.0 g.L-1, contact time 24 h, agitation speed=120 rpm, pH 6.

Fig. 5: Isotherm model plot three dyes (a) GRL (c) MB (d) CV adsorption (adsorbent dosage = 0.1 g, T = 298 K, Vibration average 100 rpm, and connect time 24 hr).

adsorption operation is chemical; if amount over to unit adsorption is appropriate physical operation (A F Alkaim 2013). Amount of sample standards acquired from range qe contra Ce (Fig. 5) illustrated by Table 1.

Influence of temperature and thermodynamic standards

Influence of heat another important physic-chemical operation standard due to heat modify adsorption ability (Aljeboree 2012). If value of adsorption rising with rising heat, then adsorption uptake operation. Probably because rising movement of dye particles and rising number of energetic locations for adsorption with rising heat. In the present research, rising in heat guided to rapid spread of dye particles through outer frontier strata and inner pores of adsorbent because minimal reluctance shown by sticky powers in water stage. As well, occasionally, melting of adsorbate particles influenced, ultimately important influence on elimination operation. rising in adsorption abilities at height heat probably contribute pore amount magnification (E. Demirbas 2008) Thermodynamic standard like variation in free power (ΔG), enthalpy variation (ΔH) and entropy variation (ΔS) determined utilizing following equations (Aljeboree 2012).

$$\Delta G = RT \ln Ke \tag{4}$$
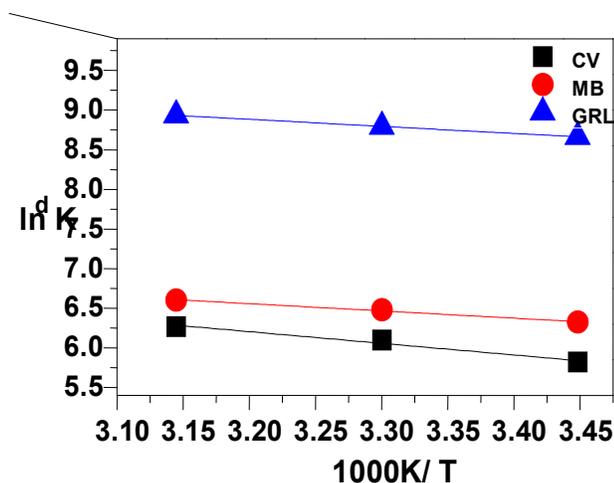
Linearized form of Van Hoff's equation for adsorption of MB,GRL,CV by *apricot stones* surface.

Fig. 6: Van't Hoff range of adsorption MB, CV, GRL *corn-cob source.*

T heat in Kelvin and R fixed gas (8.314 J/molK). Enthalpy variation (ΔH) illustrated from following equation:

$$\ln K_e = R \, \Delta S \, RT \, \Delta H + \text{"}$$ (5)

Therefore, range ln Ke vs 1/T must be directly (Fig. 6). ΔH and ΔS amount acquired from descent and object of range, sequentially. Parameter free power variation (ΔG), parameter enthalpy variation (ΔH), and parameter entropy variation (ΔS), acquired from Eqs. (4) and (5) and amounts connected with adsorption MB, CV, GRL *corn-cob source* shown in Fig 6. Negative rates ΔG refer probability of operation and unrestrained nature of adsorption with top execution MB, CV,GRL for *corn-cob source* Positive rate ΔH refer endothermic nature of operation MB, GRL, CV, whilst positive rate ΔS indicates consanguinity of adsorbents MB, CV, GRL offers some structural variation in adsorbate 78.86, 90.72, 97.63. Outcomes (Fig. 6) refers adsorption operation was endothermic in nature MB, GRL , CV negative rate of Gibbs free power variation (ΔG) expose adsorption operation unrestrained in nature (M. Kumar 2013) reduction rate ΔG with rising heat illustrated unrestrained nature of adsorption MB, CV, GRL. Entropy variation ΔS illustrated positive rate, emphasizes rising random between solid–sol mediator over adsorption operation, possibly because desorption of dissolvent particles before (MB,CV,GRL) dyes adsorption.

Conclusion

Corn-cob source solid food waste, effectively utilized such as a low cost alternative adsorbent for eliminate of dangerous textile dyes (MB, CV and GRL). Turning vertices FTIR spectrum approved MB, CV and GRL dyes adsorption *corn-cob source* SEM search as well prop it by monitoring variation in surface morphology of adsorbent. The balance state between adsorbent in sol and adsorbent surface virtually illustrating in 24 h. As well adsorption Isotherms of dyes *corn-cob source* studied and tested utilizing three Isotherm samples with more than three –standards. Freundlich>Temkin >Langmuir >Thermodynamic explain the study of spontaneous nature and heat of adsorption operation MB, GRL, CV because of negative values of both free energy change.

References

Cazetta, A.L., A.M. Vargas, E.M. Nogami, M.H. Kunita, M.R. Guilherme, A.C. Martins, T.L. Silva, J.G. Moraes and V.C. Almeida (2011). "NaOH-activated carbon of high surface area produced from coconut shell: Kinetics and equilibrium studies from the methylene blue adsorption." **174**: 117-125.

A F Alkaim, M.B.A. (2013). "Adsorption of basic yellow dye from aqueous solutions by Activated carbon derived from waste apricot stones (ASAC): Equilibrium, and thermodynamic aspects." *International journal of chemical sciences*, **11(2):** 797-814.

Abbas, A., A. M. A.-A., T. Laoui, M.J. Al-Marri, M.S. Nasser, M. Khraisheh and M.A. Atieh (2016). Heavy metal removal from aqueous solution by advanced carbon nanotubes: critical review of adsorption applications. *Separ. Purif. Technol.*, **157:** 141-161.

Saeed, A., M.S. and M. Iqbal (2010). Application potential of grapefruit peel as dye sorbent: Kinetics, equilibrium and mechanism of crystal violet adsorption. *J. Hazard. Mater*, **179:** 564-572.

Hari, A.C., R. A. P., D.A. Sabatini and T.C.G. Kibbey (2005). "Effects of pH and cationic and nonionic surfactants on the adsorption of pharmaceuticals to a natural aquifer material. *Environ. Sci. Technol.*, **39(8):** 2592-2598.

Al-Degs, Y.S., M.I. El-Barghouthi, A.H. El-Sheikh and G.M. Walker (2008). Effect of solution pH, ionic strength, and temperature on adsorption behavior of reactive dyes on activated carbon. *Dyes Pigments*, **77:** 16-23.

Aljeboree, A.M. (2015). Adsorption of methylene blue dye by using modified Fe/Attapulgite clay. Research *Journal of Pharmaceutical, Biological and Chemical Sciences*, **6(4):** 778.

Aljeboree, A.M., A.N. Alshirifi, *et al.*, (2012). Kinetics and equilibrium study for the adsorption of textile dyes on coconut shell activated carbon. *Arabian Journal of Chemistry*, **10:** S3381-S3393.

AM, A. (2016). Adsorption of crystal violet dye by Fugas Sawdust from aqueous solution. *International Journal of Chem Tech Research*, **9(3):** 412-423.

AM Aljeboree, A.A. and A.H. Al-Dujaili (2015). Adsorption

isotherm, kinetic modeling and thermodynamics of crystal violet dye on coconut husk-based activated carbon. *Desalination and Water Treatment*, **53(13):** 3656-3667.

Aseel, M. Aljeboree, A.F.A. Ammar and H. Al-Dujaili (2015). Adsorption isotherm, kinetic modeling and thermodynamics of crystal violet dye on coconut husk-based activated carbon. *Desalination and Water Treatment*, **53(13):** 3656-3667.

Aseel, M. and A.N.A. Aljeboree (2018). Adsorption of Pharmaceuticals as emerging contaminants from aqueous solutions on to friendly surfaces such as activated carbon: A review. *J. Pharm. Sci. & Res.*, **10(9):** 2252-2257

Aseel, M., A.N.A. Kadim Aljebori (2012). Effect of Different Parameters on the Adsorption of Textile Dye Maxilon Blue GRL from Aqueous Solution by Using White Marble. *Asian Journal of Chemistry*, **24 (12):** 5813-5816.

Auta, M. and B.H. Hameed (2011). Optimized waste tea activated carbon for adsorption of methylene blue and acid blue 29 dyes using response surface methodology. *Chem. Eng. J.*, **175:** 233-243.

Ayad, Fadhil Alkaim, Z. S., D.M. Mahdi, S.M. Alshrefi, A.M. Al-Sammarraie, F.M. Alamgir, P.M. Singh and A.M. Aljeboree (2015). Preparation, structure and adsorption properties of synthesized multiwall carbon nanotubes for highly effective removal of maxilon blue dye. *Korean Journal of Chemical Engineering*, **32 (12):** 2456-2462.

B. Hayati, N.M.M. (2012). Modification of activated carbon by the alkaline treatmentto remove the dyes from wastewater: mechanism, isotherm and kinetic. *Desalin. Water Treat.*, **47:** 322-333.

D. K. Mahmoud, M. A. M. S., W. A.W.A. Karim, A. Idris and Z. Z. Abidin (2012). Batch adsorption of basic dye using acid treated kenaf fibre char: equilibrium, kinetic and thermodynamic studies. *Chemical Engineering Journal*, **181:** 449-457.

E. Demirbas, K. K. and a. M.T.S. (2008). *Bioresour. Technol.*, **99:** 5368.

Langmuir, I. (1916). The constitution and fundamental properties of solids and liquids. *J. Am. Chem. Soc.*, **38:** 2221-2295.

M. Kumar, R.T. a. V.S. (2013). *Carbohydr. Polym.*, **98:** 505.

O. Aksakal, H.U. (2010). Equilibrium, kinetic and thermodynamic studies of the biosorption of textile dye (Reactive Red 195) onto *Pinus sylvestris* L. *J. Hazard. Mater*, **181:** 666-672.

Prahas, D., Y. Kartika, N. Indraswati and S. Ismadji (2008). Activated carbon from jackfruit peel waste by H3PO4 chemical activation: pore structure and surface chemistry characterization. *Chem. Eng. J.*, **140:** 32-42.

Chakraborty, S.S.C. and P.D. Saha (2011). Adsorption of crystal violet from aqueous solution onto NaOH-modified rice husk, Carbohydr. *Polym.*, **86:** 1533-1541.