ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Comparative Adsorption of an Acid Dye with Different Activation of Fly Ash

Dimple Master[1], Mehali Mehta[2]
[1]Student, M.E-Environmental Engineering, [2] Asst. Professor, Civil Engineering Department, Sarvajanik College of Engineering and Technology, Surat, Gujarat, India
master_189dimple@yahoo.in

Abstract

Adsorption technology involving use of low cost adsorbent provides an economical and eco-friendly option for treating dye wastewaters studded with different type and concentration of various organic pollutants. Present work focuses on various activation techniques of fly ash and its use as an adsorbent. An activation technique of fly ash includes heat treatment (CFA 600), Alkali treatment (CFA NaOH) and Acid treatment (CFA HCl). From experimental study it was observed that raw coal fly ash CFA and CFA HCl had superior adsorbing ability than two modified coal fly ashes (CFA-600 and CFA-NaOH) for the dye Acid Orange 7 (AO7). The adsorption capacities followed the order CFA HCl > CFA> CFA-600 > CFA-NaOH. The adsorptions of AO7 onto CFA, CFA-600, CFA HCl and CFA-NaOH all followed pseudo-second-order kinetics. The isotherm for the adsorption of AO7 onto the raw and modified coal fly ashes fits the Temkin isotherm. This study includes the application of these adsorbents in batch application by varying the parameters such as dosage of adsorbent, contact time, initial concentration, and pH.

Key words: Adsorption, Coal fly ash, Kinetics, Isotherms, AO7.

Introduction

Adsorption is the process through which a substance, originally present in one phase, is removed from that phase by accumulation at the interface between that phase and a separate (solid) phase. In principle adsorption can occur at any solid fluid interface. Adsorption is one of the established unit operations used for the treatment of contaminated water i.e. raw water and/or wastewater. Adsorption studies are usually conducted over batch studies and column studies. Activated carbon is the most used adsorbent. Due to its high cost and considering the enormous quantity of effluent produced by textile industries, researches are turning toward the use of alternative adsorbents, also called non-conventional low-cost adsorbents.

Many industries like plastics, paper, textile and cosmetics use dyes to color their products. These dyes are common water pollutants and they may be frequently found in trace quantities in industrial wastewater. Their presence in water, even at very low concentrations, is highly visible and undesirable. In addition, many dyes are difficult to degrade due to their complex aromatic structure and they tend to persist in the environment and creating serious water quality and public health problems. Therefore, it would be advantageous to develop technologies to eliminate them. Dyes can be effectively removed by adsorption process in which dissolved dye compounds were attached to the surface of adsorbents [26].

Numerous studies have been conducted to assess the harm impacts of colorants on the ecosystem. It was found that dyes may cause problems in water in several ways:

i. Dyes can have acute and/or chronic effects on exposed organisms with this depending on the dye concentration and on the exposure time.
ii. Dyes are inherently highly visible, minor release of effluent may cause abnormal coloration of surface waters which captures the attention of both the public and the authorities.
iii. The ability of dyes to absorb/reflect sunlight entering the water, this has drastic effects on the growth of bacteria and upsets their biological activity.
iv. Dyes have many different and complicated molecular structures and therefore, are difficult to treat and interfere with municipal waste treatment operations.
v. Dyes in wastewater undergo chemical and biological changes, consume dissolved oxygen from the stream and destroy aquatic life.

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

vi. Dyes have a tendency to sequester metal ions producing micro toxicity to fish and other organisms [26].

Increasing demand for energy throughout the world has led to an increase in the utilization of coal and, subsequently, in producing large quantities of fly ash as a waste product [6].

The disposal of coal fly ash from coal based power plant is a problem of global concern today. In India, most of the utility thermal power and sub-bituminous coal with high ash content (30-50%) resulting in the huge quantity of fly ash. Only a small portion of this huge quantity is used as a raw material for concrete manufacturing and construction purposes, remainder being simply dumped on the landfill sites. Currently, more than 90 million tons of fly ash is being generated annually in India, with 65000 acres of land being occupied by ash ponds. Without proper disposal options, such a huge quantity of ash has posed a great threat to the environment [37].

Since fly ash is enriched with SiO_2 and Al_2O_3, this waste product can be transformed into zeolite-like crystalline materials as a result of chemical treatment. Zeolite is porous material with large surface area and cavities of the basket-like frame. Hence, it has been used for various purposes, e.g., absorbent and ion exchanger in water and wastewater treatment [6].

Materials and methods

Preparation of Adsorbents

Dry coal fly ash is collected from coal fired boiler with the help of electrostatic precipitators or bag house filter. It is being stored and used directly as adsorbent or used for activation or modification to use it as adsorbent.

Modification of Fly ash

Heat treatment

One portion of the coal fly ash sample is washed for removal of soluble impurities and oven dried for 105°C for 24 hours and then used as adsorbent(CFA).

Another portion of the coal fly ash sample was treated in a furnace at 600 °C for 4 h and then stored in a desiccator prior to use (CFA- 600) [41, 43].

Alkali treatment

The CFA sample is treated with 1 M sodium hydroxide (NaOH) solution in 10:1 (NaOH:CFA) ratio and then the mixture was kept on a hot plate at 100 °C for 24 h. After agitation, the solid was recovered by filtration and washed thoroughly with water to remove excess NaOH. The recovered product, termed as modified fly ash, was dried at 105 °C for 24 h and used for the adsorption study (CFA-NaOH) [34, 35, 41].

Acid treatment

The sample was oven-dried at 105 °C for 24 h before use. The fly ash was treated in a 1 M solution of HCl at a solution to fly ash ratio of 2:1 by weight. The mixture was then incubated at 100 °C for 24 h. At the end of the treatment, the mixture was filtered, washed thoroughly and oven-dried at 105 °C for 24 h. The final solid products were then subjected to adsorption studies (CFA-HCl) [6, 35, 33, 41].

Preparation of Adsorbate

Acid Orange dye C.I 7 was used as the adsorbate in this study. AO7 has maximum UV-Vis absorbance at a wavelength of 490 nm. An accurately weighed quantity of the dye was dissolved in distilled water to prepare a stock solution (1000 mg/L). Experimental solutions of the desired concentrations were obtained through successive dilutions with distilled water.

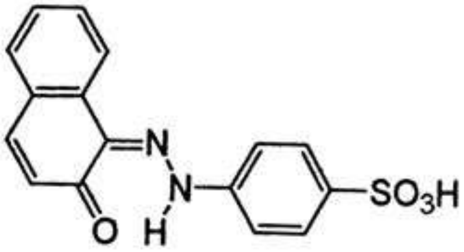


Figure 2.2.1 Structure Of An Acid Orange 7 Dye

Molecular formula: $C_{16}H_{11}N_2NaO_4S$ (Sodium Salt)
Molecular weight: 350.33 g/mol

Experimental Method

Dye adsorptions on the prepared adsorbents were carried out in a batch system to determine their dye removal capacity. A desired amount of adsorbent is added to the synthetic dye solution of known concentration and known quantity. This practical is carried out at different pH for determining optimal pH at which adsorbent give best result. pH is adjusted using 0.1 M HNO_3 and 0.1 M NaOH. The solution was agitated by the use of magnetic stirrer at room temperature. The samples were withdrawn from the experimental flask at pre-determined time intervals. Then the dye solution is separated from the adsorbent by using filter paper to ensure the solution is free from adsorbent before measuring the residual dye concentration.

Adsorption kinetics and isotherm experiments for the various CFA samples were undertaken in a batch equilibrium system. For kinetics studies, the adsorption of AO7 was studied after adding the adsorbent into an aqueous solution containing AO7 (10–30 mg/L) and stirred at various reaction times. The equilibrium, which was determined by dynamic adsorption studies, was established within 1–1.5 h; therefore, the contact time was fixed at 1.5 h. The adsorption isotherms of AO7 were studied after adding adsorbent into the aqueous solution containing a desired AR1 concentration (10–30 mg/L)

Analytical method

The UV scans of the samples were done using UV-visible spectrophotometer which range is 200 nm to 800 nm. Decolourization was determined by measuring the absorbance of the solution at the 490 nm wavelength. The decolourization of dye was detected using a spectrophotometer and the decolourization ratio was calculated from the following equation.

Color Removal (%) = $\frac{A_i - A_f}{A_i} \times 100$

where,

A_i= Absorbance before Treatment, A_f = Absorbance after Treatment.

The adsorption capacity of dyes was then calculated from

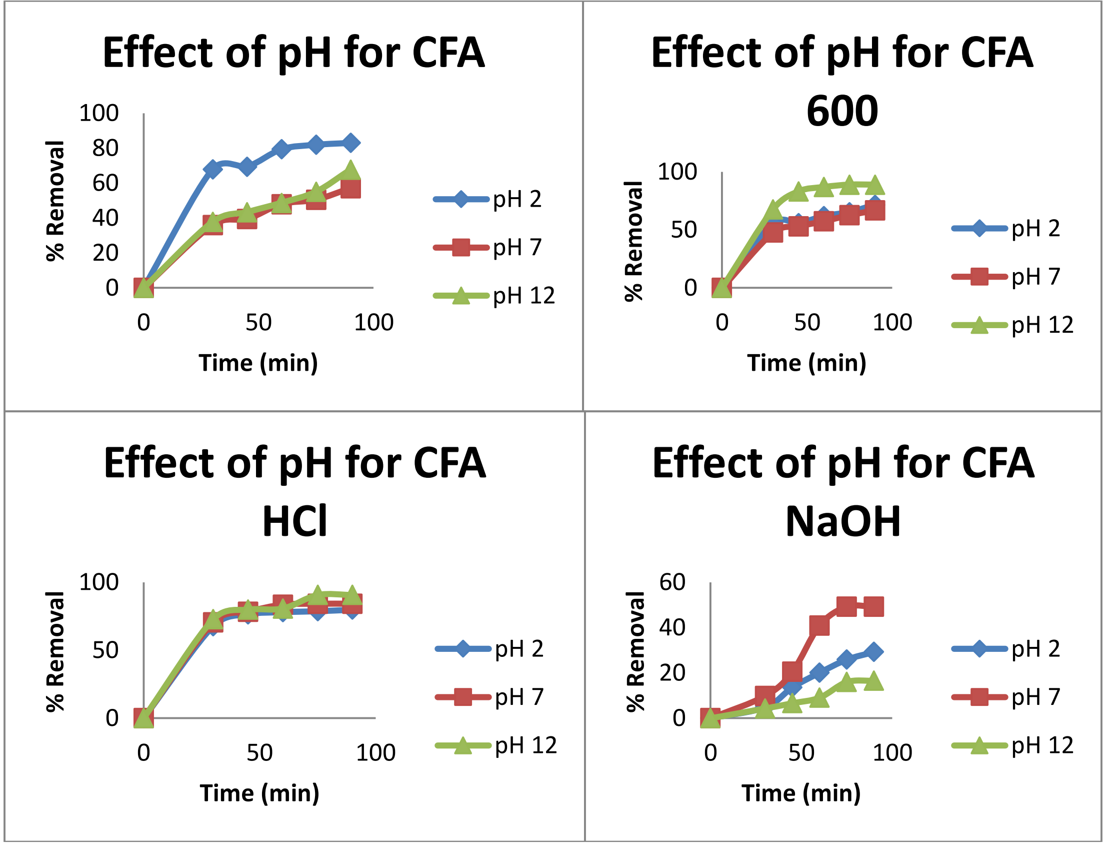
$$Q_e = \frac{V\Delta C}{m}$$

Where, V is the volume of the liquid phase, m is the mass of the solid, and ΔC is computed simply from the difference between initial and final concentration obtained from UV readings.

Results and discussion

Effect of Initial pH of dye solution

The effect of initial pH of the dye solution on the amount of dye adsorbed was studied by varying the initial pH of dye solution and keeping the other process parameters as constant. Maximum color removal obtained at lower pH for CFA sample. At Higher pH value i.e at pH 12 both activation CFA 600 and CFA HCl gives maximum removal. Activation CFA NaOH yield maximum color removal at neutral pH.



Effect of pH for CFA

Effect of pH for CFA 600

Effect of pH for CFA HCl

Effect of pH for CFA NaOH

Figure 3.1 Graphs Showing Effect of pH

Effect of Adsorbent dosage

For dye concentration of 15 mg/L effect of dosage of different adsorbent were studied by varying dosage from 0.1 to 0.3 gm/100 ml, keeping pH and initial dye concentration as constant. The results are shown in the figure. For CFA and CFA HCl activation 0.25 gm of adsorbent dosage gives 100 percent dye removal within one hour. Further increase in dosage was not required. This can be seen from nearly constant percentage removal obtained for higher dosages. It is obvious that an increase in adsorbent dosage increases available surface area and active cites.

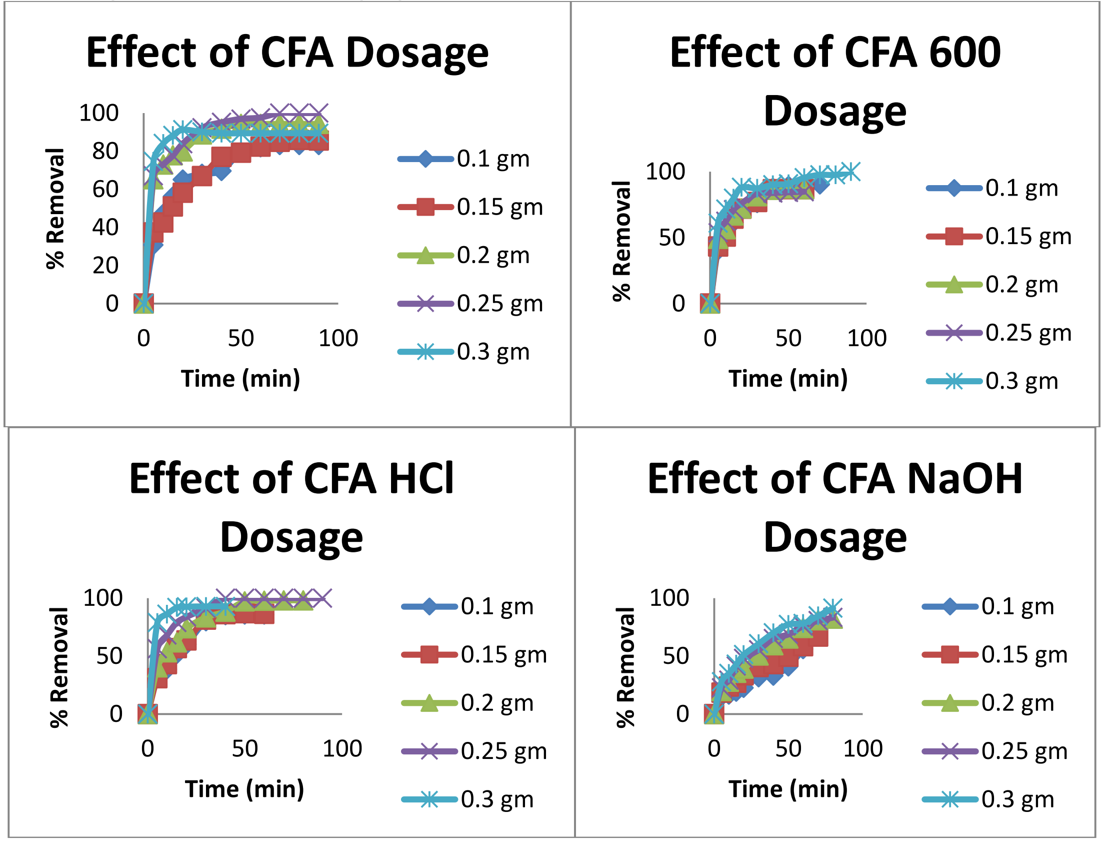
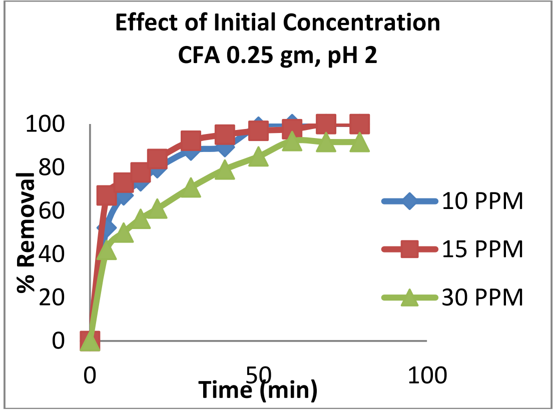
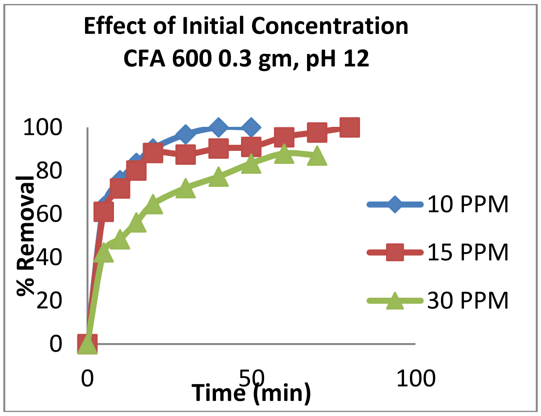


Figure 3.2 Graphs Showing Effect of adsorbent dosage

Effect of Initial dye concentration

The effect of initial dye concentration on percentage removal is shown in figure. It is seen from figure that dye adsorption increases with increase in initial concentration of dye. Same figure also indicates that the percentage removal was found to decrease with increase in the initial concentration of dye while the amount of dye adsorption increases with increase in initial concentration. The reason may be that there exists reduction in immediate solute adsorption owing to lack of active sites required for high initial concentration of dye.





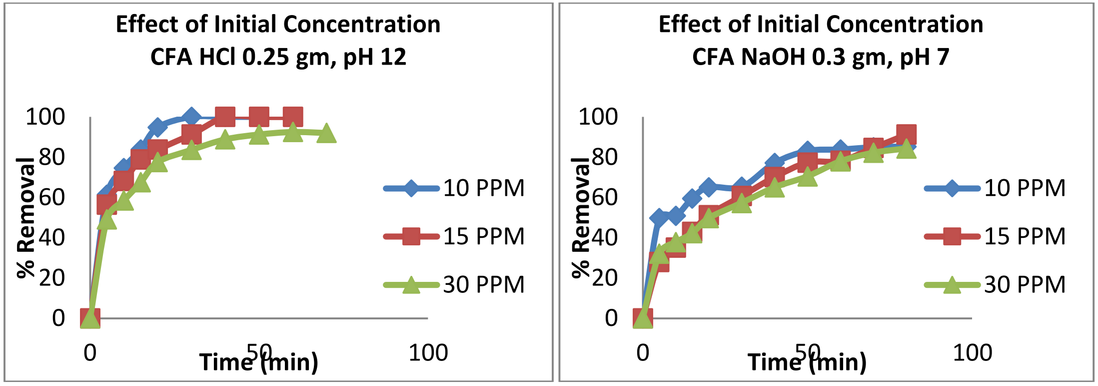


Figure 3.1 Graphs Showing Effect Initial Dye Concentration

Adsorption Isotherm

Equilibrium data commonly known as adsorption isotherms are basic requirements for the design of adsorption systems. These data provide information on the capacity of the adsorbent or the amount required to remove a unit mass of pollutant under the system conditions. Langmuir and Freundlich isotherms were used to describe the equilibrium characteristics of adsorption. An accurate isotherm is important for design purposes. Linear regression is commonly used to determine the best fit model, and the method of least squares has been widely used for obtaining the isotherm constants.

One of the most popular adsorption isotherms used for liquids to describe adsorption on a surface having heterogeneous energy distribution is Freundlich isotherm. It is given as:

$$q_e = K_F C_e^{1/n}$$

Freundlich isotherm is derived assuming heterogeneity surface. K_F and n are indicators of adsorption capacity and adsorption intensity, respectively. Rearranging Equation we get,

$$\ln q_e = \ln K_F + \frac{1}{n} \ln C_e$$

A plot of log q_e versus log C_e yields a straight line, with a slope of 1/n and intercept of ln K_F. The value of Freundlich constant (n) should lie in the range of 1–10 for favourable adsorption.

Langmuir isotherm, applicable for homogenous surface adsorption, is given as:

$$q_e = q_m \frac{K_L C_e}{1 + K_L C_e}$$

Above equation can be rearranged into linear form:

$$\frac{1}{q_e} = \frac{1}{q_m K_L C_e} + \frac{1}{q_m}$$

By plotting 1/q_e versus 1/C_e, the Langmuir constants can be obtained. The essential characteristics of Langmuir isotherm can be expressed by a separation or equilibrium parameter, which is a dimensionless constant defined as:

$$R_L = \frac{1}{1 + K_L C_0}$$

R_L indicates the nature of adsorption as indicated below:

- Unfavourable $R_L > 1$;
- Linear $R_L = 1$;
- Favourable $0 < R_L < 1$;
- Irreversible $R_L = 0$.

Temkin Adsorption Isotherm model is given by,

$$q_e = \ln AC_e$$

It's linear expression, $q_e = \ln A + \ln C_e$

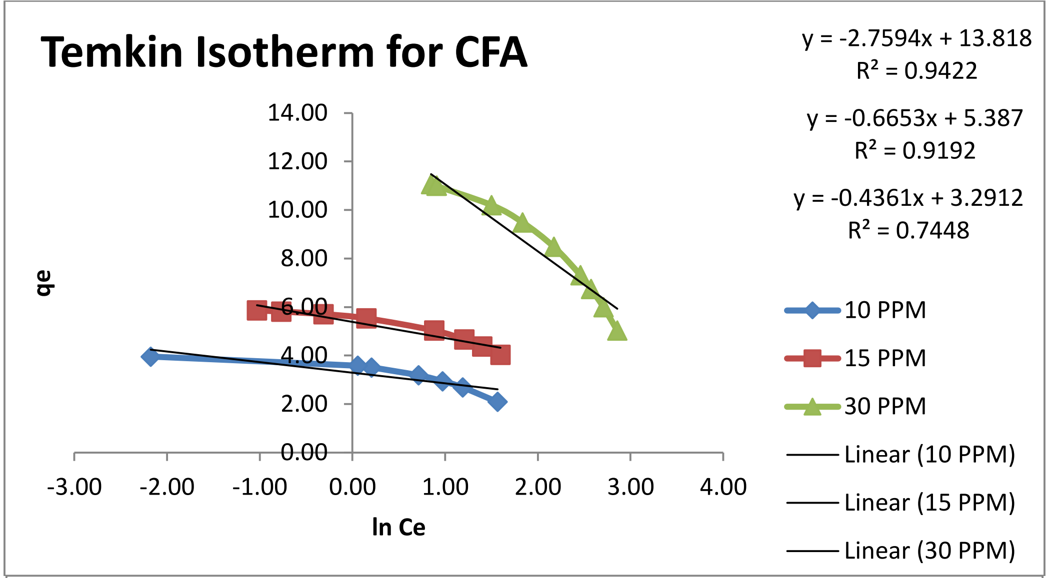
Where A is the equilibrium binding constant related to the heat of adsorption. The plot of q_e Vs ln C_e is used to determine the isotherm constant A. The basic assumptions of this model are that the heat of adsorption of the ions in a layer decreases linearly due to the adsorbent – adsorbate interaction and that the binding energies are uniformly distributed.

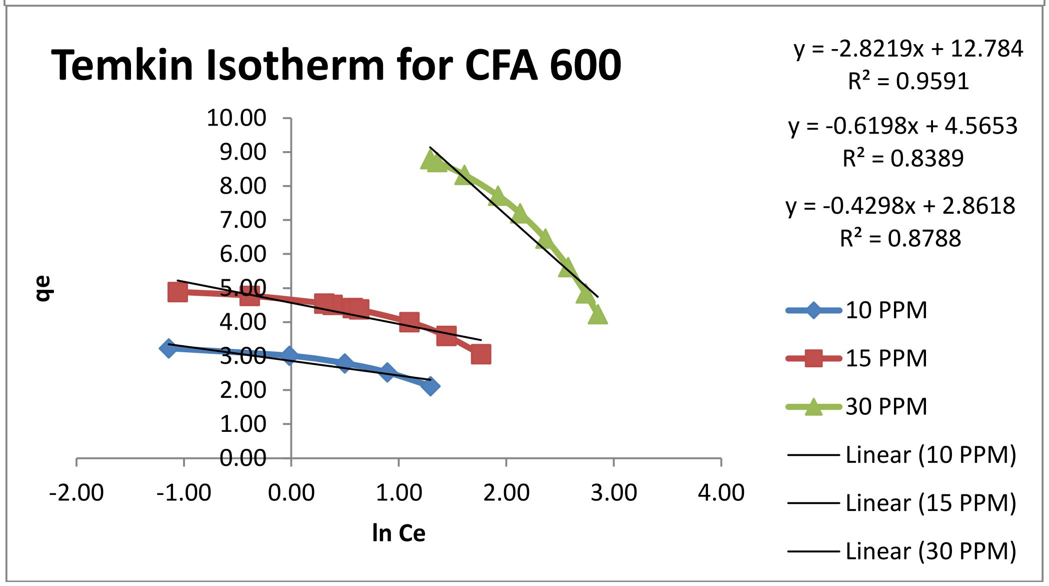
Nomenclature

C_0 initial dye concentration in aqueous solution (mg/dm^3)
C_e equilibrium dye concentration in liquid phase (mg/dm^3)
Ct dye concentration in aqueous solution at time t (mg/dm^3)
D adsorbent dosage (g/dm^3)
K_1 pseudo-first-order rate constant (min^{-1})
K_2 pseudo-second order rate constant (g mg^{-1} min^{-1})
K_F Freundlich constant (mg g^{-1}) (dm^3/mg)$^{1/n}$
K_i intraparticle diffusion rate constant (mg g^{-1} min$^{0.5}$)
K_L Langmuir adsorption constant (dm^3 mg^{-1})
1/n Freundlich parameter
q_e equilibrium dye concentration in solid phase (mg g^{-1})
$q_{eq,ex}$ equilibrium dye concentration in solid phase

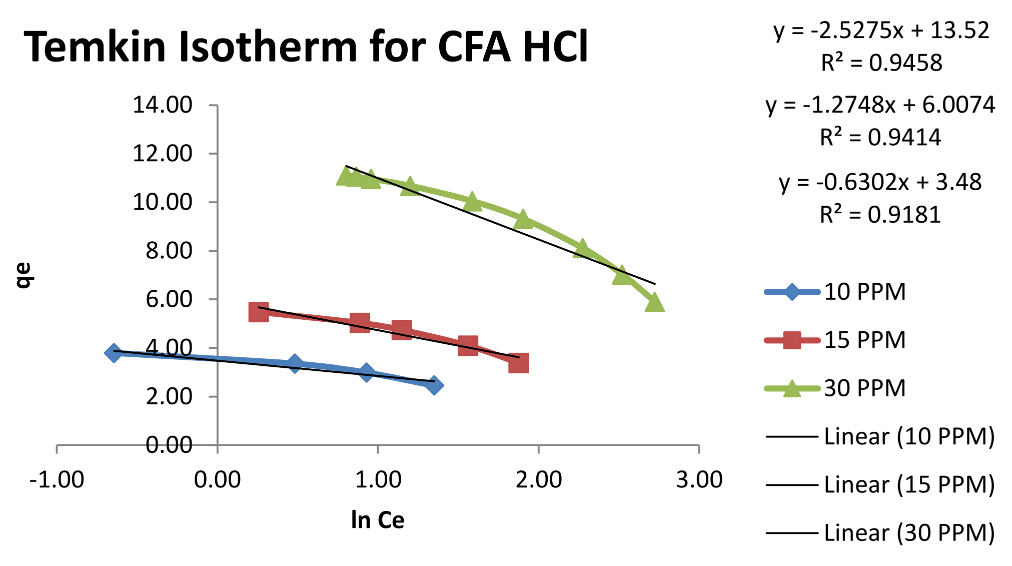
obtained from experiments (mg g^{-1})
$q$eq,$_{th}$ equilibrium dye concentration in solid phase predicted from models (mg g−1)
q_m Langmuir isotherm parameter, maximum dye adsorbed/unit mass of adsorbent (mg g^{-1})
q_t amount of dye adsorbed per unit mass of adsorbent at time t (mg g^{-1})
R_L Langmuir separation or equilibrium parameter
t time (min)

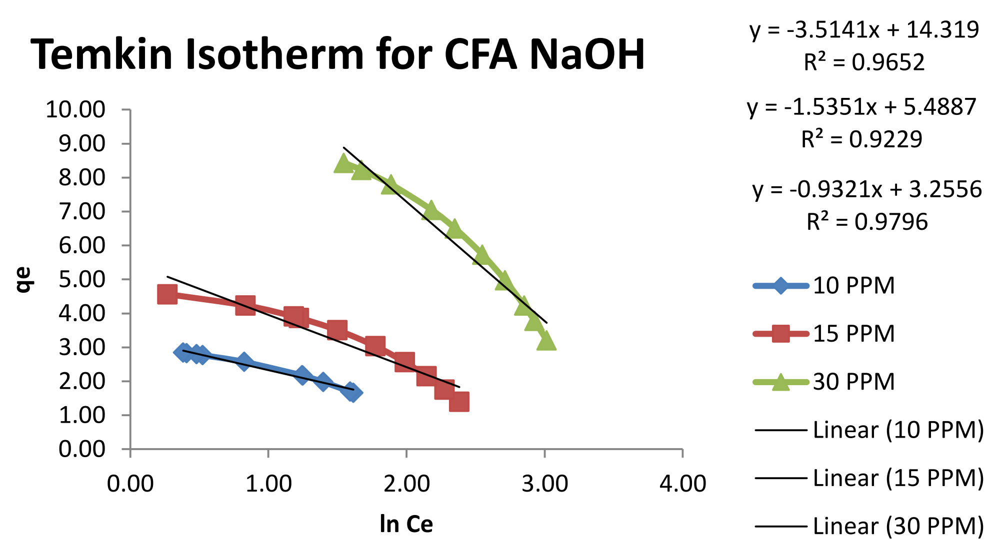
The values of Q_m, K_L, R_L, K_F, n, A and the linear regression correlations for the Langmuir, Freundlich and Temkin isotherms are given in Table 1. Because the regression coefficients (R^2) for the Langmuir, Freundlich and Temkin isotherm were 0.3791–0.8428, 0.6597-9557 and 0.7448–0.9796, respectively, it appears that the Temkin model yielded a much better fit than the Langmuir and Freundlich model. For the four adsorbents, the maximum adsorption capacities (Q_m) at various concentrations decreased in the order 30 > 15 > 10 mg/L.





ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852





Adsorbent	Dye Conc.	Langmuir				Freundlich			Temkin	
		Qm	K_L	R_L	R^2	N	K_F	R^2	A	R^2
CFA	**10**	2.19	2.15	0.04	0.7021	3.63	15.26	0.8052	26.88	0.7448
	15	4.48	9.38	0.01	0.637	9.64	5.56	0.8116	218.55	0.9192
	30	6.11	0.84	0.04	0.6442	10.21	3.50	0.6597	1002492	0.9422
CFA 600	**10**	2.40	0.02	0.86	0.5214	2.31	16.53	0.915	17.48	0.8788
	15	3.78	9.29	0.01	0.3791	6.49	4.55	0.7935	96.09	0.8389
	30	4.58	0.49	0.06	0.7053	6.26	2.84	0.8375	356468	0.9591
CFA HCl	**10**	2.65	5.82	0.02	0.6391	4.97	3.46	0.8788	32.46	0.9181
	15	3.54	1.88	0.03	0.6717	3.46	6.24	0.9061	406.43	0.9414
	30	6.74	0.98	0.03	0.686	3.42	14.83	0.9058	744152	0.9458
CFA NaOH	**10**	1.58	1.41	0.07	0.8428	2.43	3.44	0.9557	25.94	0.9796
	15	1.94	0.96	0.07	0.4564	1.86	6.69	0.8353	241.94	0.9229
	30	3.51	0.3	0.1	0.681	1.63	24.49	0.9084	1654484	0.9652

Table 1 Langmuir, Freundlich and Temkin constants for CFA, CFA-600, CFA HCl and CFA-NaOH

Adsorption kinetic studies

The transient behaviour of the dye sorption process was analysed by using the pseudo-first-order, pseudo-second-order, and intraparticle diffusion models. Application of a single kinetic model to sorption on solid adsorbents may be questionable because of the heterogeneity of adsorbent surfaces and diversity of adsorption phenomena.

3.5.1. Pseudo-first-order model

The pseudo-first-order kinetic model has been widely used to predict dye adsorption kinetics. The pseudo-first-order rate expression suggested originally by Lagergren based on solid capacity is expressed as follows.

$$\frac{dq_t}{dt} = K_1(q_e - q_t)$$

Integrating and applying boundary conditions $q_t|_{t=0}$ = 0 and $q_t|_{t=t}$ = q_t we get,

$\ln(q_e - q_t) = \ln q_e - K_1 t$

Values of q_e and K_1 can be obtained from the slope and intercept of the plot $\ln(q_e - q_t)$ versus t.

3.5.2. Pseudo-second order model

Pseudo-second order model is expressed by the equation.

$$\frac{dq_t}{dt} = K_2(q_e - q_t)^2$$

Integrating and applying boundary conditions $q_t|_{t=0}$ = 0 and $q_t|_{t=t}$ = q_t we get,

$$\frac{1}{q_e - q_t} = \frac{1}{q_e} + K_2 t$$

We can rearrange above equation as:

$$\frac{t}{q_t} = \frac{1}{K_2 q_e^2} + \frac{t}{q_e}$$

Values of q_e and K_2 can be obtained from the slope and intercept of the plot t/q_t versus t.

3.5.3. Intraparticle diffusion studies

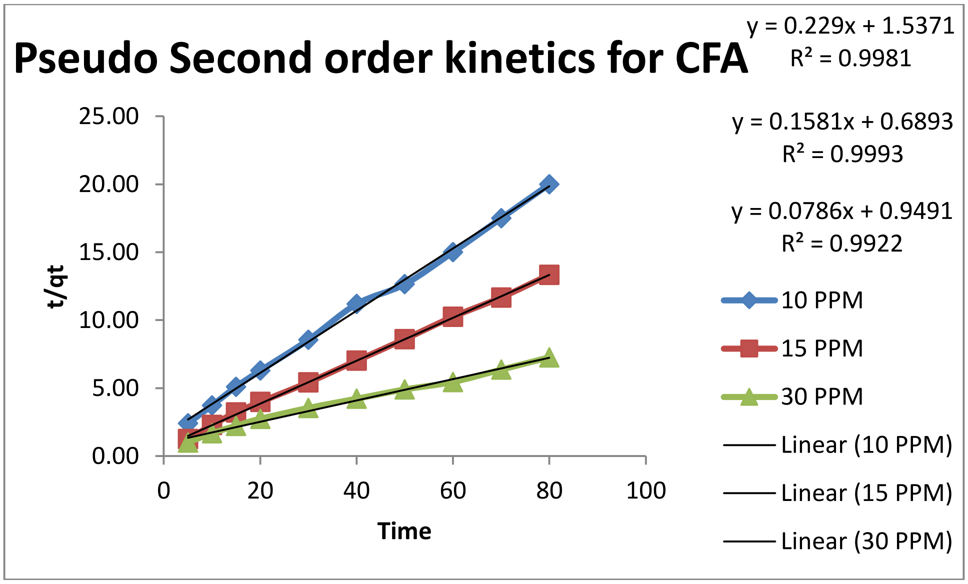
It is necessary to identify the steps involved during adsorption in order to interpret the mechanism of adsorption. It is assumed that the adsorption process consists of several steps. Migration of the dye from the bulk of the solution to the sorbent surface, diffusion of the dye through the boundary layer, intraparticle diffusion, and adsorption of the dye on the internal sorbent surface.

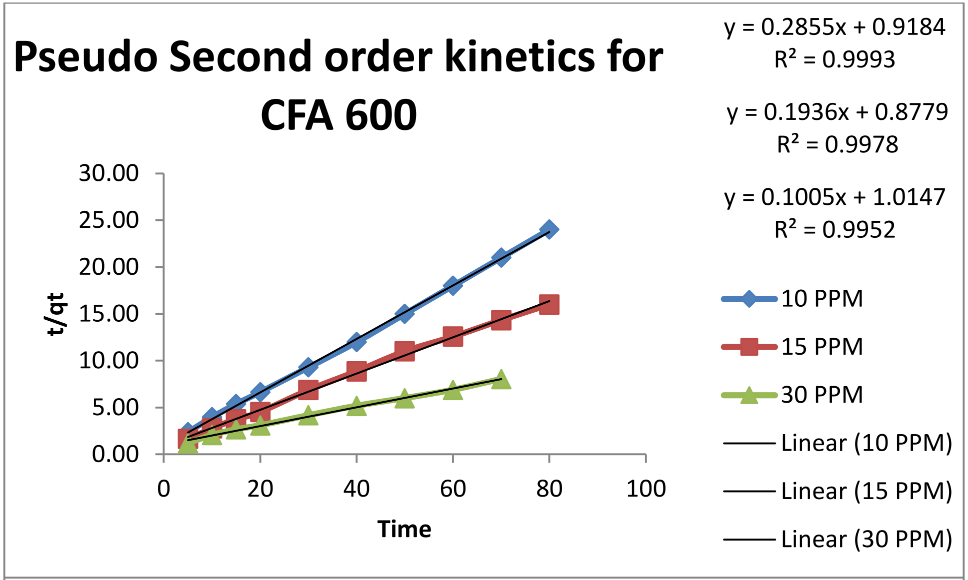
The intraparticle diffusion rate can be expressed in terms of the square root time. The mathematical dependence of q_t versus $t^{0.5}$ is obtained if the sorption process is considered to be influenced by diffusion in the spherical particles and convective diffusion in the solution. The root time dependence, the intraparticle diffusion model is defined as follows:

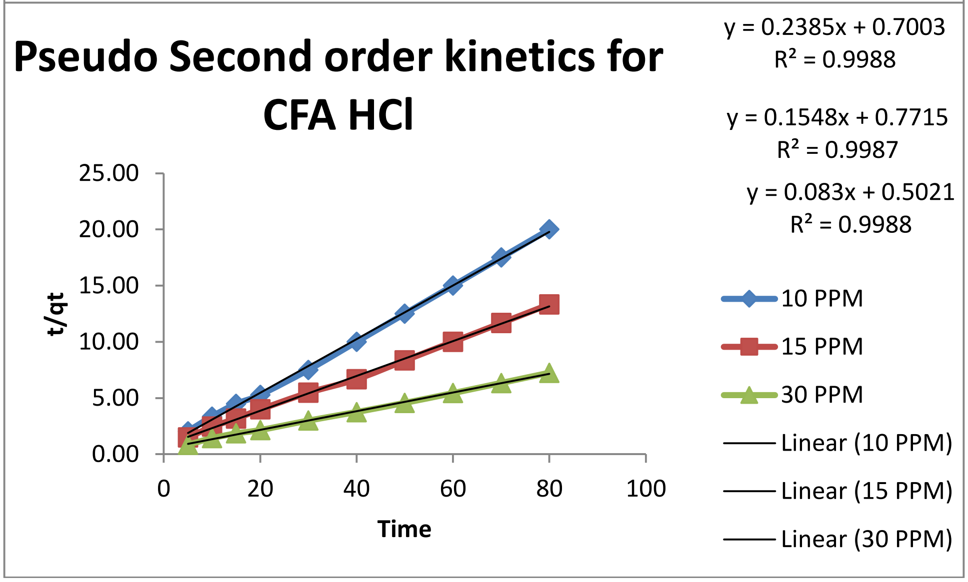
$$q_t = K_i t^{0.5} + I$$

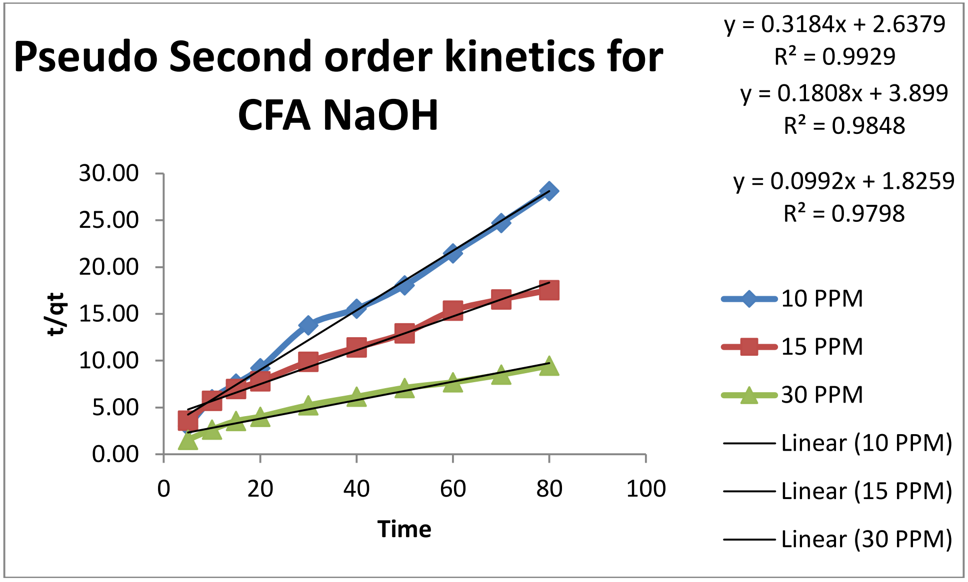
The plot q_t versus $t^{0.5}$ is given by multiple linear regions representing the external mass transfer followed by intraparticle or pore diffusion.

The experimental data for the different CFA samples were fitted using the pseudo-first-order, pseudo-second-order kinetics, and intraparticle diffusion models. Table 2 lists the parameters obtained using each of the models. The pseudo-first-order and intraparticle diffusion models did not represent the kinetics well; i.e., their regression coefficients were lower than those obtained using the second-order kinetics model. The linearity of the plots of t/Q_t versus t (linear regression coefficients: >0.980) confirmed the pseudo-second-order nature of the process.




Pseudo Second order kinetics for CFA 600
y = 0.2855x + 0.9184
R² = 0.9993
y = 0.1936x + 0.8779
R² = 0.9978
y = 0.1005x + 1.0147
R² = 0.9952
t/qt
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
20
40
60
80
100
Time
10 PPM
15 PPM
30 PPM
Linear (10 PPM)
Linear (15 PPM)
Linear (30 PPM)


Pseudo Second order kinetics for CFA HCl
y = 0.2385x + 0.7003
R² = 0.9988
y = 0.1548x + 0.7715
R² = 0.9987
y = 0.083x + 0.5021
R² = 0.9988
t/qt
25.00
20.00
15.00
10.00
5.00
0.00
0
20
40
60
80
100
Time
10 PPM
15 PPM
30 PPM
Linear (10 PPM)
Linear (15 PPM)
Linear (30 PPM)



Adsorbent	Dye Conc.	Pseudo first Order kinetics			Pseudo second Order kinetics			Intraparticle Diffusion	
		K_1	Q_e	R^2	K_2	Q_e	R^2	K_I	R^2
CFA	**10**	0.0506	6.73	0.9822	0.0341	4.37	0.9981	0.2763	0.9222
	15	0.0574	2.00	0.9657	0.0363	6.33	0.9993	0.3045	0.9295
	30	0.0823	2.35	0.8793	0.0065	12.72	0.9922	0.9672	0.9782
CFA 600	**10**	0.1157	1.44	0.9401	0.0888	3.50	0.9993	0.167	0.7981
	15	0.0406	1.6	0.9364	0.0427	5.17	0.9978	0.2486	0.88
	30	0.0615	5.23	0.9778	0.0099	9.95	0.9952	0.7794	0.9757
CFA HCl	**10**	0.1286	1.78	0.9339	0.0812	4.19	0.9988	0.2024	0.7171
	15	0.0782	2.75	0.9794	0.0311	6.46	0.9987	0.38	0.8562
	30	0.1019	6.89	0.9805	0.0137	12.05	0.9988	0.7692	0.875
CFA NaOH	**10**	0.0825	2.02	0.9469	0.0384	3.14	0.9929	0.2006	0.9504
	15	0.0369	3.32	0.9844	0.0084	5.53	0.9848	0.4744	0.9908
	30	0.0491	6.76	0.9399	0.0054	10.08	0.9798	0.8265	0.9959

Table 2 Kinetic parameters of AO7 on CFA, CFA-600, CFA HCl and CFA-NaOH at various Concentrations

Conclusions

The conclusions drawn from the present study are summarized as follows:

1. The adsorption capacities of CFA, CFA 600, CFA HCl and CFA NaOH toward AO7 were 4.37-12.72, 3.50-9.95, 4.19-12.05 and 3.14-10.08 mg/g respectively.
2. The experimental adsorption data is reasonably follows the freundlich and Temkin Isotherms and follows pseudo second order rate kinetics.
3. The equilibrium between Dye solution and adsorbent surface is established within 1.5 hours.
4. The amount of adsorbate adsorbed increases with an increase in adsorbent dosage as well as increases with increase in initial dye concentration.
5. It is also confirmed that untreated fly ash and HCl modified fly ash has greater dye removal capacity than other activation.

Reference

1. A K A Rathi, S A Puranik, “Chemical Industry Wastewater Treatment Using Adsorption”, Journal Of Scientific & Industrial Research”, Vol. 61, January 2002, pp 53-60.
2. Ahsan Habib, Nazrul Islam, Anarul Islam and A. M. Shafiqul Alam, “Removal of Copper from Aqueous Solution Using Orange Peel, Sawdust and Bagasse”, Pak. J. Anal. Environ. Chem. Vol. 8, No. 1 & 2 (2007) 21. 25, ISSN-1996-918X.
3. Alinnor I. J. and Nwachukwu M. A., “A study on removal characteristics of para-nitrophenol from aqueous solution by fly ash”, Journal of

Environmental Chemistry and Ecotoxicology Vol. 3(2), pp. 32-36, February 2011, ISSN 2141-226X

4. Ashly Leena Prasad and Thirumalisamy Santhi, "Adsorption of hazardous cationic dyes from aqueous solution onto Acacia nilotica leaves as an eco-friendly adsorbent", Sustain. Environ. Res., 22(2), 113-122 (2012).
5. Atun G., Hisarh G., Kurtoglu A. E., Ayar N., "A comparision of basic dye adsorption onto zeolitic materials synthesized from fly ash", Journal of Hazardous Materials. 187: 562: 573.
6. C. H. Weng, Y. T. Lin, T. W. Tzeng, "Removal of methylene blue from aqueous solution by adsorption onto pineapple leaf powder", J.Hazard. Mater. (2009)170, 417-424.
7. Carolyn Palma, Andrea Carvajal, Carlos Vásquez and Elsa Contreras, "Wastewater Treatment for Removal of Recalcitrant Compounds: A Hybrid Process for Decolorization and Biodegradation of Dyes", Separation Science And Engineering Chinese Journal of Chemical Engineering, 19(4) 621—625 (2011)
8. CD Woolard, K Petrus and M van der Horst, "The use of a modified fly ash as an adsorbent for lead", Department of Chemistry, University of Port Elizabeth, PO Box 1600, Port Elizabeth 6000, South Africa.
9. Charu Saxena and Sangeeta Madan, "Evaluation Of Adsorbents Efficacy For The Removal Of Pollutants From Sugar Mill Effluent", ARPN Journal of Agricultural and Biological Science, VOL. 7, NO. 5, MAY 2012 ISSN 1990-6145
10. Chayada Pansuk, Soydoa Vinitnantharat, "A Comparative Study of the Adsorption of Acid Brown 75 and Direct Yellow 162 onto Unmodified and Surfactant Modified Granule Developed from Coal Fly Ash", 2011 2nd International Conference on Environmental Science and Technology IPCBEE vol.6.
11. Debasis Goswami and Arabinda K. Das, "Removal of fluoride from drinking water using a modified fly ash adsorbent", Journal of Scientific & Industrial Research, Vol. 65, January 2006, pp. 77-79.
12. El Sayed Zakaria El-Ashtoukhy, "Removal of Indigo Carmine Dye from Synthetic Wastewater by Electrochemical Oxidation in a New Cell with Horizontally Oriented Electrodes", Int. J. Electrochem. Sci., 8 (2013) 846 – 858
13. H. Polat, A. Vengoshb, I. Pankratovb, M. Polat, "A new methodology for removal of boron from water by coal and fly ash", Elsevier desalination 164 (2004) 173-188
14. I. Maghri, A. Kenz, M. Elkoual, O. Tanane, M. Talbi, "Textile Dyes removal from industrial waste water by mytilus edulis shells", J. Mater. Environ. Sci. 3 (1) (2012) 121-136 ISSN : 2028-2508
15. Kunwar P. Singh, Dinesh Mohan, Sarita Sinha, G. S. Tondon, and Devlina Gosh, "Color Removal from Wastewater Using Low-Cost Activated Carbon Derived from Agricultural Waste Material", Ind. Eng. Chem. Res. 2003, 42, 1965-1976.
16. Lakdawala M. M. and Nimavat K. S., "The influence of low cost material Fly ash to the removal of COD content of Sugar Industry waste water", Elixir International Journal Applied Chemistry 35 (2011) 2953-2955
17. N. Kannan, S. Murugavel, "Comparative Study On The Removal Of Acid Violet By Adsorption On Various Low Cost Adsorbents", Global Nest Journal, Vol 10, No 3, Pp 395-403, 2008.
18. Nagarethinam Kannan, Mariappan Minakshisundaram, "Adsorption of Congo red on Various Activated Carbons", A Comparative Study, Water, Air and Soil Pollution, Kluwer Academic Publishers, 138: 289-305, 2002
19. Namasivayam, C. and Ranganathan, K. (1993), "Waste Fe(III)/Cr(III) hydroxide as adsorbent for the removal of Cr(VI) from aqueous solution and chromium plating industry wastewater", Environmental Pollution, Vol. 82, pp. 255-261.
20. Namita Tewari, V K Verma and J P N Rai, "Comparative Evaluation of natural adsorbent for pollutants removal from distillery spent wash", Journal of Scientific & Industrial Research, Vol. 65, November 2006, pp. 935-938.
21. O. Yavuz, A.H. Aydin, "Removal of Direct Dyes from Aqueous Solution Using Various Adsorbents", Polish Jounal of Environmental Studies Vol. 15, No. 1(2006). 155-161
22. Olugbenga Solomon Bello, Oluwole Abraham Olusegun and Victor Obinna Njoku, "Fly ash: an alternative to powdered activated carbon for the removal of eosin dye from aqueous solutions", Bull. Chem. Soc. Ethiop. 2013, 27(2), 191-204. ISSN 1011-3924.
23. Olushola S. Ayanda, Olalekan S. Fatoki, Folahan A. Adekola, and Bhekumusa J.

Ximba, “Activated Carbon-Fly Ash-Nanometal Oxide Composite Materials: Preparation, Characterization, and Tributyltin Removal Efficiency”, Hindawi Publishing Corporation Journal of Chemistry, Volume 2013, Article ID 148129.

24. P. K. Sahoo, S. Tripathy, M. K. Panigrahi, “Evaluation of the use of an alkali modified fly ash as a potential adsorbent for the removal of metals from acid mine drainage”, Appl Water Sci 10.1007/s13201-013-0113-2.
25. P. Pengthamkeerati, T. Satapanajaru, P. Chularuengoaksorn, “Chemical modification of coal fly ash for the removal of phosphate from aqueous solution”, Elsevier Fuel 87 (2008) 2469–2476
26. R. Jain, N. Sharma and K. Radhapyari, “Removal of hazardous azo dye metalin yellow from industrial wastewater using electrochemical technique”, European Water 27/28: 43-52, 2009, E.W Publications.
27. Ratna, Padhi. B.S, “Pollution due to synthetic dyes toxicity & carcinogenicity studies and remediation”, International Journal Of Environmental Sciences Volume 3, No 3, 2012, ISSN 0976 – 4402
28. Ravi Kant Singh, Deepak Kumar Gupta, Shashi Kumar, Surendra Kumar, “Utilization Of Fly Ash As Biologically Activated Carbon On Microbial Consortium For The Removal Of Pollutants From Waste Water”, International Journal of Advanced Biotechnology and Research ISSN 0976-2612, Online ISSN 2278–599X, Vol 4, Issue 1, 2013, pp 20-28
29. Rita Kant, “Textile dyeing industry an environmental hazard”, Natural Science Vol.4, No.1, 22-26 (2012)
30. S. Laxmi Gayatri, Md. Ahmaruzzaman, “Adsorption technique for the removal of phenolic compounds from wastewater using low-cost natural adsorbents”, Assam University Journal of Science & Technology: Physical Sciences and Technology Vol. 5 Number II 156-166, 2010.
31. S. Saiful Azhar, Ghaniey Liew, Suhardy, Farizul Hafiz, Irfan Hatim, “Dye Removal from Aqueous Solution by using Adsorption on Treated Sugarcane Bagasse”, American Journal of Applied Sciences 2 (11): 1499-1503, 2005 ISSN 1546-9239
32. S.C.Nawle, S.V.Patil, “Experimental studies on acetic acid removal from waste water using fly ash”, Institute Of Technology, Nirma University, Ahmedabad – 382 481, 08-10 December, 2011
33. Samson Oluwaseyi BADA and Sanja POTGIETER-VERMAAK, “Evaluation and Treatment of Coal Fly Ash for Adsorption”, Application School of Chemical and Metallurgical Engineering, Faculty of Engineering and the Built Environment, University of the Witwatersrand, P/Bag X3 Wits 2050 Johannesburg, South Africa.
34. Satya Vani Yadla, V. Sridevi and M.V.V.Chandana Lakshmi, “A Review on Adsorption of Heavy Metals from Aqueous Solution”, Journal of Chemical, Biological and Physical Sciences, May-July.2012, Vol.2.No.3, 1585-1593. e- ISSN: 2249 –1929
35. Siti Zuraida, M., Nurhaslina,C.R., Ku Halim Ku Hamid, “Removal of Synthetic Dyes from Wastewater by Using Bacteria, Lactobacillus delbruckii”, International Refereed Journal of Engineering and Science (IRJES) ISSN (Online) 2319-183X, Volume 2, Issue 5(May 2013), PP.01-07
36. Sivakumar Durairaj and Shankar Durairaj, “Colour Removal from Textile Industry Wastewater Using Low Cost Adsorbents”, International Journal of Chemical, Environmental and Pharmaceutical Research, Vol. 3, No.1, January-April, 2012, 52-57.
37. Sunil J. Kulkarni, Suhas, V Patil and Y.P.Bhalerao, “Experimental Studies of Bagasse Flyash Adsorption on Chemical Oxygen Demand and Dissolved Oxygen of the Distillery Waste”, Institute Of Technology, Nirma University, Ahmedabad – 382 481, 08-10 December, 2011
38. Sunil J. Kulkarni, Sonali R. Dhokpande, Dr. Jayant P. Kaware, “Studies On Flyash As An Adsorbent For Removal Of Various Pollutants From Wastewater”, International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 5, May - 2013 ISSN: 2278-0181
39. T. Viraraghvan, “Ash Utilization in Water Quality Management”, Faculty of Engineering, University of Regina, Saskatchewan, Canada, SAS 0A2
40. T.A. Albanis, D.G. Hela, T.M. Sakellarides, T.G. Danis, “Removal of Dyes from aqueous solutions by Adsorption on Mixtures of Flyash and soil in Batch and Column technques”
41. Ting-Chu Hsu, “Adsorption of an acid dye onto coal fly ash”, Elsevier Fuel 87 (2008) 3040–3045
42. V. Ponnusami, V. Krithika, R. Madhuram, S.N. Srivastava, “Biosorption of reactive dye

using acid-treated rice husk: factorial design analysis", J. Hazard. Mater. 142 (2007) 397–403.

43. V.O. Ojijo, M.S. Onyango, Aoyi Ochieng and F.A.O. Otieno, "Decolourization of Melanoidin Containing Wastewater Using South African Coal Fly Ash", International Journal of Civil and Environmental Engineering 2:1 2010
44. Velmurugan .P, Rathina kumar.V, Dhinakaran.G., "Dye removal from aqueous solution using low cost adsorbent", International Journal of Environmental Sciences Volume 1, No 7, 2011, ISSN 0976 – 4402
45. X. querol, N.moreno, J.C. Umana, A. alstuey, E. Hernandez, A. Lopez-Soler, F. Plana, "Synthesis of Zeolites from coal fly ash: an overview", Elsevier International jounal of coal geology 50(2002)413-423

BOOKS

1. Zaharia Carmen and Suteu Daniela, Organic Pollutants Ten Years After the Stockholm Convention - Environmental and Analytical Update, InTech Publisher, ISBN 978-953-307-917-2
2. Allen RLM (1971). Colour Chemistry. London: Thomas Nelson and Sons Ltd. pp. 11–13.
3. Aspland JR (1997). Textile Dyeing and Coloration. Association of Textile Chemists and Colorists. pp. 3–310.
4. Abrahart EN (1977). Dyes and their Intermediates. New York: Chemical Publishing. pp. 1–12.
5. Water supply & sanitary Engineering, G.S Birdie, J.S Birdie, Dhanpat Rai Publishing Company
6. Mass Transfer operation by Treybal, McGraw Hill Publishing House

WEB SITE

http://www.worlddyevariety.com/acid-dyes/acid-orange-7.html