Dyes are extensively used in many industries such as textile, paper, food, rubber, cosmetics as well plastics in order to colour their products. Wastewater from these industries contains dye pollutants which is the culprit of the environmental contamination. Color effluents discharged from dye production industries in wastewater is aesthetically unpleasant because they interfere with the penetration of light into the water increasing the biological oxygen demand thereby cause the disturbances in the aquatic life. Dyes also cause many health problems to human beings such as dysfunction of the kidney, liver, brain, reproductive system, and central nervous system. Without adequate treatment these dyes can remain in the environment for a long period of time. Due to toxicity of dyes and their degradation products, it is necessary to eliminate dyes from wastewater before its discharge to aqueous media.

The treatment of wastewater using affordable and environment friendly techniques remains an important challenge for environmentalists. Various techniques, including flocculation, oxidation and electrolysis, UV/Fenton, photocatalysis, ion exchange, electrochemical degradation and adsorption have been employed for removal of dyes from wastewaters. Some of these methods are effective only if concentration of dye in waste water is small; some produce a large amount of waste material, disposal of the sludge increases the operation cost. Some toxic byproducts are produced after chemical treatments which are hazardous to the environment. Adsorption has been found to be superior to other techniques for water re-use in terms of initial cost, flexibility and simplicity of design, ease of operation and insensitivity to toxic pollutants. Adsorption also does not result in the formation of harmful substances. Various researchers have reviewed the use of low cost adsorbents for the removal of dyes.

In the present research programme, the novel adsorbents from agriculture waste (ground nut shells, local waste) and Eichhornia crassipes (a worst weed) were prepared and studied its potential for the removal of dyes from aqueous solutions under different conditions. The adsorbents were further modified by surfactants to enhance their
Summary

adsorption capacity. Modification is accomplished in a very simple way involving mixing and stirring. The use of these biosorbents makes adsorption a selective and inexpensive technology. The results obtained from extensive research on adsorbent generation, kinetics, mechanism to define its adsorption capacity are compiled in this thesis.

Highly porous materials offer a number of potential advantages as adsorbents including larger pore volume and diameter, high surface area and regular channel type structures. The main scopes in present research work is to achieve the specified objectives comprises of research activities such as preparation and modification of the adsorbents, the characterization of the adsorbents and the adsorption capacity study specifically for dyes congo red, safranin, crystal violet and basic blue 9. Three types of mesoporous adsorbents MCM-41, MCM-48 and SBA-3 are synthesized with little modification in the method reported in the literature. We have also synthesized a new mesoporous material using ferrocene based surfactant as a template and tetraethylorthosilicate as silica source, abbreviated as FMM. Characterization techniques confirmed its mesoporosity, crystallinity, nanosize particles and good surface area. FMM evidenced high adsorption capacity for dye congo red. Its potential can be explored further for effluent treatment containing different dyes. Thesis is divided into six chapters.

Chapter 1: Introduction

A brief account of literature on removal of dyes using low cost adsorbents and mesoporous materials has been discussed.

Chapter 2: Experimental Methodology

The experimental procedure with detailed information on the reagents, instruments and techniques used to obtain results are discussed in this chapter.

Chapter 3: Adsorption studies of dye Congo red

The results of the adsorption of congo red by different adsorbents have been discussed under following four section (3.1 to 3.4).
Section 3.1: Adsorption studies of dye congo red (CR) by ground nut shells charcoal (GNC) and eichhornia charcoal (EC).

The removal of dye congo red (CR) from aqueous solutions by two low cost adsorbents such as ground nut shells charcoal (GNC) and eichhornia charcoal (EC) under various experimental conditions was investigated in this section. The characterization of the adsorbents GNC and EC were carried out using Fourier transform infrared (FTIR), Scanning electronic microscope (SEM) and X-ray diffraction (XRD) techniques.

Batch studies were carried out to investigate the effect of contact time, pH, temperatures, adsorbent dose, ionic strength of salts (sodium chloride, NaCl and potassium chloride, KCl) and initial dye concentration on the removal of dye CR. The equilibrium time for GNC was 80, 60 and 30 minutes and for EC was 90, 60 and 40 minutes were required at 308, 313 and 318K respectively. Results denotes that when pH value of CR solution increased from 2 to 12, the percentage of dye adsorption sharply reduced from 94 to 73% in case of GNC and 75 to 51% in case of EC.

With increase in the adsorbent dose of GNC and EC from 0.1 to 1.2 g in 100 mL of CR dye solution, dye uptake increases from 83-95% and 60-82% for GNC and EC respectively. Five models such as Pseudo first order, Pseudo-second order, Intra-particle diffusion, Elovich and Bangham’s models have been used to study the parameters of kinetics of adsorption of dye congo red. Results implied that adsorption of congo red on these adsorbents (GNC and EC) nicely followed the second order kinetic model. Various isotherm equations have been used such as Freundlich, Langmuir, Dubinin and Radushkevich (D-R), Temkin equations and Non ideal competitive adsorption (NICA) model. Experimental data well fitted to Langmuir isotherm model and maximum adsorption capacity was found to be 117.6 and 56.8 mg g\(^{-1}\) for GNC and EC at 318K. Thermodynamic parameters insinuated that the adsorption process is feasible, spontaneous and endothermic in nature for both the adsorbents.

Section 3.2 Adsorption of dye congo red (CR) by surfactant (cetyltrimethyl ammonium bromide, CTAB) modified eichhornia charcoal (CTAB-EC).

In this section, the surface of eichhornia charcoal (EC) is modified with cationic surfactant cetyltrimethyl ammonium bromide (CTAB) and used it as an adsorbent
(CTAB-EC) for the adsorption of dye congo red (CR) from aqueous solutions. The characterization of adsorbent was done by Fourier transform infrared spectra (FTIR), Brunauer-Emmett-Teller (BET), X-ray diffraction (XRD), Scanning electron microscope (SEM), Boehm titration and point of zero charge measurements. The total basic groups, total acidic groups and total functionalized groups are 3.1, 0.75 and 3.85 mmol g\(^{-1}\) respectively. The Brunauer Emmett Teller (BET) surface area, pore volume, monolayer volume and molecular cross sectional area were measured to be 20 m\(^2\) g\(^{-1}\), 0.0099 m\(^2\) g\(^{-1}\), 4.52 cm\(^3\) g\(^{-1}\) and 0.162 nm\(^2\), respectively.

FTIR spectrum displays major bands at 2924, 2723, 1586, 1458, 1376, 1030 and 722 cm\(^{-1}\) for unloaded adsorbent (CTAB-EC). However the intensities of the peaks is reduced when dye CR get loaded on the surface of adsorbent CTAB-EC. SEM images showed the heterogeneous pores within CTAB-EC particle where adsorption could occur. After adsorption the pores were packed with dye CR molecules. The equilibrium time for dye CR onto CTAB-EC comes out 270, 180 and 140 minutes at 303, 313 and 323 K respectively. With increase in adsorbent dose of CTAB-EC from 0.1 to 1.0 g, the percentage removal increases upto 95%.

Experimental data were contemplated for various kinetic models and isotherm models. It was interpreted that adsorption kinetics followed second order kinetic model. Langmuir model deduced the maximum adsorption capacity as 103.2 mg g\(^{-1}\) at 323K. Thermodynamic parameters; Gibbs’s free energy change (\(\Delta G\)), enthalpy change (\(\Delta H\)) and entropy change (\(\Delta S\)) have been calculated and the present adsorption system is speculated as spontaneous, feasible and endothermic in nature.

**Section 3.3 Synthesis, characterization and adsorptive behavior of mesoporous material SBA-3 toward dye congo red (CR).**

Mesoporous material SBA-3 is characterized and used as an adsorbent for the removal of dye congo red (CR) from aqueous solutions. The well resolved peaks at 2\(\theta\)=2.2\(^{\circ}\) in XRD patterns of SBA-3 demonstrate the hexagonally ordered structure, which is indicative of well ordered mesoporous structure and crystalline nature of mesoporous material. Scanning electron microscope (SEM) images depicted the formation of spherical nanoparticles.
Nitrogen adsorption studies carried out where the isotherms can be classified as type IV isotherms. According to Brunauer-Emmett-Teller (BET) method, the specific surface area (SBET) and pore volume are estimated to be $690 \text{ m}^2 \text{ g}^{-1}$ and $0.17-0.23 \text{ cm}^3 \text{ g}^{-1}$, respectively. The rate of adsorption of the dye onto SBA-3 was very high, and equilibrium was attained within 15–30 minutes of contact for initial dye concentration of $60 \text{ mg L}^{-1}$ whereas 100 min are sufficient for the initial dye concentration of $200 \text{ mg L}^{-1}$. Adsorption kinetics analysis reveals that the adsorption is governed by pseudo-second-order model. Intraparticle diffusion analysis indicated that the process may be controlled by more than one mode of diffusion controlled mechanism. At low dye concentration, it is film diffusion whereas at higher concentration, particle diffusion is the prevalent one. Adsorption capacity ($K_F$) decreases with increase in temperature, which revealed the exothermic nature of adsorption process which is strengthened by decrease in values of monolayer capacity (Cm) and equilibrium binding constant ($K_T$). The thermodynamic parameters insinuated that adsorption process is a feasible, spontaneous, exothermic, and entropically favorable. Maximum monolayer capacity was found to be $344.8 \text{ mg g}^{-1}$ at $303 \text{ K}$.

**Section 3.4 Synthesis, characterization and adsorptive behavior of ferrocene based mesoporous material (FMM) toward dye congo red (CR).**

Characterization and adsorptive application of ferrocene based mesoporous material (FMM) for the adsorption of azo dye congo red (CR) is discussed in this section. XRD pattern evidenced an intense peak at $2 \theta = 0.7^\circ$, which is the characteristic of mesoporous material and reflections associated with hexagonal symmetry.

According to Brunauer-Emmett-Teller (BET) method, the specific surface area (SBET) and pore volume are estimated to be $342 \text{ m}^2 \text{ g}^{-1}$ and $1.51 \text{ cm}^3 \text{ g}^{-1}$, respectively. Barrett–Joyner–Halenda (BJH) average pore width was found to be $19.4 \text{ nm}$. Mesoporous silica prepared from ferrocene based template has a spherical morphology as displayed in the scanning electron microscope (SEM) picture. TEM images of FMM, shows nanosized particles of near sphere with hollow interior structure.
Summary

Adsorption of dye CR on FMM increases with increase in contact time, initial dye concentration, adsorbent dose and temperature. 86% removal occurred in ten minutes and 96% in 60 minutes. Adsorption capacity (K_F), amount of dye adsorbed at equilibrium (q_e), maximum adsorption capacity (C_m), and heat of adsorption (B) increases with increase in temperature revealed the endothermic nature of the adsorption of CR on FMM. Langmuir model imparted high value of monolayer capacity as 312.5 mg g⁻¹. The values of thermodynamic parameters like enthalpy change (ΔH) and entropy change (ΔS) were found to be 49.94 kJ mol⁻¹ and 265.5 J K⁻¹mol⁻¹ respectively, and negative values of ΔG and positive values of ΔH corroborated that the present adsorption system is feasible, spontaneous and endothermic.

Chapter 4: Adsorption studies of dye Safranin

The results of adsorption of dye safranin onto different adsorbents have been discussed under following three headings (4.1 to 4.3).

Section 4.1 Adsorptive and kinetic study of dye safranin onto eichhornia charcoal (EC) and surface modified eichhornia charcoal.

In this section we discussed the preparation of adsorbents eichhornia charcoal (EC), eichhornia charcoal modified with surfactant sodium dodecylsulphate (EC-SDS) and combination of both surfactant and salt sodium chloride (EC-SDS-NaCl). Adsorption of safranin on adsorbents was fast and the equilibrium was achieved by 220, 200, 180 min for EC; 210, 180, 160 minutes for EC-SDS and 180, 140 and 120 minutes for EC-SDS-NaCl at 303, 313 and 323 K respectively. This trend is ascribed to electrostatic attraction of positively charged dye molecules and negatively charged surface of adsorbent. pH_{ZPC} (pH at zero point charge) of adsorbents EC, EC-SDS and EC-SDS-NaCl was found to be 7.8, 7.95 and 8.0 respectively. At higher pH values (pH > pH_{ZPC}) the surface of adsorbents may acquire a negative charge imparting increase in dye uptake due to the electrostatic force of attraction. Therefore, all of the adsorption studies were performed at pH 8. When adsorbent dosages were varied from 0.25 to 1.5 g for initial dye concentration of 40 mg L⁻¹ for EC, EC-SDS and EC-SDS-NaCl removal efficiency increased from 68 to 95; 85 to 96 and 82 to 99% respectively.
Summary

Kinetic and isotherm model analyses reflected that adsorption follows pseudo-second order model and Langmuir isotherm. Obtained isotherm constants and kinetic parameters increased with increase in temperature, specified that adsorption process is endothermic. It is further confirmed by the positive value of $\Delta H$ (enthalpy change). Value of $E$, $n$ and $b_T$ (D-R, Freundlich and Temkin constants) concluded that adsorption process is physical in nature. It is also strengthened by the low values for the Arrhenius activation energy 2.26, 18.02 and 27.42 kJ mol$^{-1}$ for EC, EC-SDS and EC-SDS-NaCl respectively. Thermodynamic data manifested that the adsorption process is endothermic, spontaneous and feasible. It is demonstrated that adsorption is maximum for EC-SDS-NaCl and follows the order EC< EC-SDS < EC-SDS-NaCl with monolayer capacity of 58.8, 69.4 and 84.8 mg g$^{-1}$ respectively at 323K.

Section 4.2 Synthesis, characterization and adsorptive behavior of mesoporous material MCM-41 toward dye safranin

Mesoporous material MCM-41 was synthesized with little modification in the method reported in literature and examined its potential for the adsorption of basic dye safranin. Brunauer Emmett Teller (BET) surface area of MCM-41 is 313 m$^2$ g$^{-1}$ and Barrett Joyner Halenda (BJH) average pore width is in the range of 6.6 to 9.8 nm.

The rate of adsorption increases with increase in contact time, initial dye concentration, adsorbent dose and pH. Results verified that adsorption capacity at equilibrium ($q_e$) increased from 16.2 to 55.1 mg g$^{-1}$ as the initial dye concentrations increased from 20 to 100 mg L$^{-1}$. However the percentage of color removal decreased by 82.1 to 55.1%. Results reflected that with increase in adsorbent dose from 0.025 to 0.1 g per 25 mL of dye solution having initial concentration 40 and 80 mgL$^{-1}$, percentage dye removal increased from 74.9 to 92.1% and 60.4 to 91.6% respectively. As the pH decreased from 10.0 to 4.0, dye removal dropped from 94.3% to 21.9%; 91.7% to 12.9%; 90.9% to 8.5% and 92.1 to 6.1% for dye concentration 20, 40, 60 and 80 mg L$^{-1}$ respectively, which could be attributed to decrease in electrostatic attractions between the safranin and MCM-41 molecules.

Langmuir isotherm is found to be more suitable and appropriate model to explain the adsorption isotherm of safranin on MCM-41. The kinetic study confirms the
Summary

Adsorption of safranin on MCM-41 follows pseudo second order rate equation. Maximum adsorption capacity was found to be 68.8, 66.7 and 63.7 mg g$^{-1}$ at 303, 313 and 323K respectively. Value of $E$, $n$ and $b_T$ (D–R, Freundlich and Tempkin constant) concluded that adsorption process is physical in nature. However Weber–Morris, Richenberg model and activation energy ($E_a$) suggested that adsorption of safranin on MCM-41 is diffusion controlled process. Thermodynamic investigations disclosed that the values of $\Delta G$ and $\Delta H$ are negative at all temperatures for the adsorbent indicating that the adsorption is exothermic and spontaneous in nature. The value of error function showed that Freundlich model best fitted at 303 and 313 K, but at higher temperature value of error function for Langmuir model is less, which proved the applicability of Langmuir model at 323K.

Section 4.3 Synthesis, characterization and adsorptive behavior of mesoporous material MCM-48 toward dye safranin

Mesoporous material MCM-48 was synthesized with little modification from the method described in literature and used as an adsorbent for the removal of cationic dye safranin. Brunauer-Emmett-Teller (BET) surface area obtained from N$_2$ adsorption desorption isotherm was 860 m$^2$ g$^{-1}$. Pore volume and pore size was found to be 0.50 cm$^3$ g$^{-1}$ and 23.29Å respectively. The scanning electron microscopy (SEM) images divulge agglomerated particles, in size (nano), and near spherical in shape. Transmission electron microscopy (TEM) images of MCM-48 also show the formation of spherical particle in nano ranges. The time necessary to achieve the equilibrium was 150 minutes. The amount of dye adsorbed ($q_t$ values) increased, whereas percentage removal decreased with increase in initial dye concentrations.

The adsorption kinetic studies revealed that the adsorption process followed the pseudo second-order kinetic model. Maximum monolayer capacity was found to be 104.17 mg g$^{-1}$ at 323K. Boyd, Richenberg model and activation energy ($E_a$) values alluded that adsorption of safranin on MCM-48 is particle diffusion controlled process. The value of adsorption activation energy ($E_a$) was found to be 35.65 kJ mol$^{-1}$. The activation energy specifies that the adsorption process is physical in nature. The values of $\Delta H^\#$ and $\Delta S^\#$ were calculated from the slope and intercept of the plot of ln ($k_s$T) vs. 1/T are 33.05 kJ mol$^{-1}$ and -187.22 J mol$^{-1}$K$^{-1}$. 245
Values of error functioned suggested that D-R model does not better fitted to the experimental data. Thermodynamic investigations surmised that the adsorption is feasible, spontaneous, endothermic and entropy increasing process.

**Chapter 5: Adsorptive removal of dye Crystal violet**

The results have been discussed in two sections.

**Section 5.1: Removal of dye crystal violet (CV) using eichhornia charcoal (EC)**

Eichhornia charcoal (EC) is used as a potential adsorbent to remove dye crystal violet (CV) from aqueous solutions. Adsorbent material (EC) was characterized for its surface chemistry by elemental analysis, Boehm titrations, point of zero charge measurements (pH$_{ZPC}$), Brunauer-Emmett-Teller (BET), Scanning electron microscope (SEM), Fourier transform infrared spectra (FTIR) and X-ray diffraction (XRD). pH of the material suspension, pH$_{ZPC}$ as well as oxygenated group contents analyzed by titration are 8.0, 7.9 and 0.034 mmol g$^{-1}$ respectively, whereas total basic group was found to be 0.047 mmol g$^{-1}$. EC contains mainly carbon (30%), nitrogen (2.5%) and hydrogen (1.64%).

Particle size, total pore volume, monolayer volume, cross sectional area and BET surface area obtained was 0.45-51µm, 0.012 m$^2$ g$^{-1}$, 5.42 cm$^3$ g$^{-1}$, 0.16 nm$^2$ and 23.63 m$^2$g$^{-1}$ respectively. Percentage dye removal increases with increase in time. The rate of adsorption is fast in the beginning and thereafter it was gradual until the equilibrium was reached. The equilibrium time at 303, 313 and 323 K was found to be 180, 150 and 120 minutes respectively. The percentage dye removal increases from 76 to 91% by decreasing the initial concentration of dye CV from 50-20 mg L$^{-1}$.

At low pH (pH=2) adsorptive removal was found to be 73%, at high pH the removal was 95%. Pseudo first order, pseudo second order, intra- particle diffusion, Elovich model and Bangham’s model were applied to experimental data.

Pseudo second order kinetic model is more suitable for explaining the adsorption kinetics of dye CV on EC. Langmuir model is found to be in good agreement with the experimental data on adsorptive behavior of the dye onto eichhornia charcoal giving adorption capacity as 58.1 mg g$^{-1}$. The values of Freundlich constant ($K_F$),
Langmuir constant ($K_L$), monolayer concentration (Cm) D–R constant ($q_d$), Temkin constant ($K_T$), and Elovich constant (a) increases with increase in temperature, which demonstrate the endothermic nature of adsorption process. It is confirmed by the positive value of enthalpy change (ΔH) and activation parameters. The value of adsorption activation energy (Ea) was found to be 31.82 kJ mol$^{-1}$. The positive value of entropy change (ΔS) and negative value of free energy change (ΔG) concluded the increase of randomness and spontaneous nature of adsorption.

Section 5.2 Surface modified eichhornia charcoal for the removal of dye crystal violet.

In this section, eichhornia charcoal (EC) is modified with sodium dodecyl sulphate (SDS) an anionic surfactant being employed as an adsorbent for the removal of dye crystal violet (CV) from aqueous solutions. Morphology and surface of the adsorbent was characterized by elemental analysis, Boehm titrations, Fourier transform infrared spectra (FTIR), X-ray diffraction (XRD), Scanning electronic microscope (SEM), Brunauer Emmett Teller (BET), and point of zero charge (pH$_{ZPC}$) techniques.

The element analysis of adsorbent EC-SDS shows 33% carbon, 2.7% nitrogen, 1.9% hydrogen and no sulphur content. Total basic group and total functionalized group obtained by Boehm titration are 0.005 and 0.009 mmol g$^{-1}$ respectively. The value of pH$_{ZPC}$ and pH for EC-SDS is 7.95 and 8 respectively. The Brunauer Emmett Teller (BET) surface area, total pore volume: and molecular cross sectional area of EC-SDS was 68.77 m$^2$ g$^{-1}$, 0.0346 m$^2$ g$^{-1}$ and 0.162 nm$^2$, respectively. The particle size of EC-SDS was found to be in the range of 0.47 to 1.5μm. SEM studies illustrated that adsorbent EC-SDS has considerable numbers of pores hence there is a good possibility for dyes to be trapped and adsorbed into these pores.

The percentage removal increases with decrease in the initial concentration of dye CV at all the studied temperatures. At lower concentrations, all dye molecules present in the solution interact with the binding sites of the adsorbent, facilitating about 94% adsorption.
Summary

With increase in pH from 2 to 10, removal efficiency increases from 85.0% to 98.3%. It is attributed to the electrostatic attraction between the negatively charged adsorption site and the positively charged dye molecules.

The rate of dye removal decreases with increase in adsorbent dose. It is to be ascribed to higher concentration of SDS leads to the formation of surfactant micelles in which dye is incorporated, thus preventing the dye being adsorbed onto the adsorbent surface hence adsorption decreases. Pseudo-second order model adequately described the adsorption process analyzed from $q_e$ (mg g$^{-1}$) and $R^2$ values. The results corroborated that experimental data were correlated reasonably well by the Langmuir adsorption isotherm. Results are strengthened by statistical analysis error model. The maximum adsorption capacity for CV on EC-SDS was found to be 116.3 mg g$^{-1}$, respectively, which is quite high in comparison to other adsorbents.

The adsorption of the dye was found to be feasible and denoted increase in randomness at interface as evidenced by $\Delta G$ and $\Delta S$ values. Mean free energy $E$ (D–R constant) and activation energy value inferred that present adsorption process is physical in nature. Intra particle diffusion constant ($k_{id}$), second-order rate constant ($k_s$), extent of surface coverage ($b$), Freundlich adsorption capacity ($K_F$), Tempkin constant ($K_T$), D–R adsorption capacity constant ($q_s$) and Langmuir monolayer capacity (Cm) increases with increase in temperature insinuated the endothermic behavior of adsorption process. It is supported by the large positive value of free energy of activation ($\Delta G^\neq$). This fact is further confirmed by the positive value of enthalpy change. The studied models demonstrated the homogenous temperature dependence of adsorption process.

Chapter 6- Adsorptive removal of dye Basic Blue 9

In this chapter, the adsorption of dye basic blue 9 (BB9) using ground nut shells charcoal (GNC), and eichhornia charcoal (EC) as adsorbents was investigated. The characterization was done with FTIR spectroscopy, scanning electron microscopy and X-ray diffraction. Batch adsorption studies have been investigated by measuring the effect of pH, adsorbent dose, adsorbate concentration, contact time, temperature, and ionic strength. Adsorption of the dye increased with increase in contact time,
temperature, and amount of adsorbent and initial concentration. The kinetic experimental data were fitted to pseudo-first order, pseudo-second order, intra-particle diffusion, Elovich model and Bangham’s model and corresponding constants were calculated and discussed. Pseudo-second order kinetics was found to describe the adsorption of dye BB9 on both the adsorbents and rate is mainly controlled by intra-particle diffusion. A study of five isotherm models; Langmuir, Freundlich, Temkin, Dubinin and Radushkevich and Non-ideal competitive adsorption isotherms have been made and important thermodynamic parameters have been obtained. The adsorption of BB9 onto GNC and EC was spontaneous and endothermic as concluded from thermodynamic assays. Experimental results confirmed that dye BB9 can be successfully removed from the aqueous solutions economically and efficiently.

The results of present study concluded that for removal of dyes using low cost adsorbents (GNC and EC) and surface modified adsorbent EC using cationic and anionic surfactant give fruitful results. Mesoporous materials show the great potential for the removal of dyes and could be used for commercial purpose. Mesoporous materials are cost effective but they have large surface area and proved good adsorbents because of their higher adsorption capacity. For dye congo red adsorption capacity of adsorbent follow the order: SBA-3> FMM> GNC> CTAB-EC>EC. Dye safranin follows the trend: MCM-48> EC-SDS-NaCl> EC-SDS> MCM-41> EC. Surfactant modified EC (EC-SDS) possessed higher adsorption capacity as compare to EC for the removal of dye crystal violet. However adsorption capacity of EC is more than GNC for dye basic blue 9. The use of the low-cost adsorbents is recommended since they are relatively cheap or of no cost, easily available, renewable or abundant natural resources and exhibit high affinity for dyes. These materials can be used as adsorbents with little or no pretreatment.