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RESEARCH ARTICLE

SYNTHESIS AND CHARACTERIZATION OF NiO NANOCOMPOSITES BY EXTREMITY APPROACH AND THEIR EFFICACY FOR THE CURE OF DYE ABETTED SIMULATED WASTE WATER

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ABSTRACT

In this research, we report a facile approach to synthesize NiO nano particles via simply sono chemical method, which revealed high proficiency and discrimination towards the adsorption of organic dyes. The structure and morphology of the nano particles were characterized by scanning electron microscopy (SEM) and fourier transform infrared (FTIR) spectroscopy. NiO nano particles were successfully employed as nano adsorbent for the treatment of congo red (CR) dye assisted simulated waste water under the influence of variable conditions to triumph best adsorption capacity. The effect of adsorbent amount, adsorbate concentration and stay time were analyzed. Adsorption isotherm models were also employed to analyze the practicability of the adsorption process. The adsorption results poved that the equilibrium data coincides very well with Langmuir and Freundlich isotherm, and the maximum adsorption propensities for Congo red (CR). The kinetic data can be interpreted by pseudo-second order model. The rational mechanism of adsorption attributed to hydrogen bonding, electrostatic attraction and ion \ exchange between the dye molecules and NiO in the adsorption progression. These reutilizing methods effectively instigated at industrial scale and therefore assess the challenges pretended by them in the environment and community health.

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INTRODUCTION

Recently, water pollution has become a serious delinquent worldwide. A large amount of effluents from industries including toxic dyes are being randomly discharged into the water system without any treatments, leading to serious environmental pollution. In addition, normal organic dyes are composed of complex aromatic structures, which are very stable in the water and difficult to remove (Ho, 2015). So far, numerous methods have been developed to treat the dye-containing wastewater, such as ozonation, oxidation, chemical coagulation/flocculation, cloud point extraction, photocatalysis, ion-exchange, forward osmosis and adsorption (Kwon *et al*., 2015; Balaz *et al*., 2015). Among these technologies, the adsorption process has been attractive because it is simple, economic and highly efficient (Mahmoodi and Masrouri, 2015). Various adsorbents including activated carbon (Liu, 2015), clays (Ho, 2015), activated alumina (Jia *et al*., 2015) and zeolite (Santos and Boaventura, 2015; Mahmoodi and Ghobadi, 2015), have been widely applied in the adsorption of dyes from waste water. Despite its wide applications and extensive research, some difficulties exist in the adsorption technology. For example, selective adsorption of certain dye from a mixture of various dyes has been rarely studied. The design of effective and selective systems for dye adsorption is highly fascinating and could be used in practical application. For example, this kind of selective system could be used as sensor for the detection of certain kinds of dyes (Liu, 2015) or recycling some valuable dyes from waste streams (Mahmoodi and Maghsoodi, 2015). In this work, we report a simple and facile strategy to synthesize NiO nano particles via ultrasonic method. The adsorption abilities of the NiO nano particles for CR were investigated. The adsorption isotherms, kinetics and mechanisms were also studied systematically (Ho, 2015). There are several procedures stated for the preparation of nanoparticles, comprising attrition, pyrolysis, radiolysis and sol-gel. Sol-gel process is one of the most extensively used methods to synthesize nanomaterials due to trite procedure and instrumentation. The pioneer in sol-gel procedure is a chemical solution which upon chemical reaction customs discrete particles as a consequence of hydrolysis and poly condensation of metal alkoxides and metal chlorides (Mariappan *et al*., 2015).

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MATERIALS AND METHODS

The removal of dye was carried out by developing simulated dye system for this purpose CR was selected for the removal studies. The Nickel II sulphate hexa hydrate and sodium hydroxide were prudently chosen to synthesize their nano particles and exploit for the removal of CR dye. All chemicals were investigative grade and uses without further purification. The solutions were prepared with deionize distilled water. Congo red has important spectrophotometric properties. Indeed, its UV-visible absorption spectrum shows a characteristic, intense peak around 498 nm in aqueous solution, at low dye concentration. Congo red's molar extinction coefficient is around 45000 (l)/ (mol) (cm).

Preparation of Dye Solutions

The concentrations of dye solutions were prepared by stock solution using distilled water. The absorbance of respective concentrations of dye was measured by UV-Vis spectrophotometer.

Preparation of Nanoparticles

NiO nanoparticles were synthesized by dissolving 100gm of $NiSO_4.6H_2O$ in 500ml distilled water. The prepared solution was added to 1M NaOH. Both solutions were mixed and the mixture was stirred for 12 hours on magnetic stirrer / shaking incubator at 200rpm at temperature 30^{o}C then suspended particles were well-found. The resulting solution was evaporated to dryness by espousing evaporation method after that the content were oven dried at 400^{o}C and NiO particles were prepared and they stored in desiccators for further use. (Zhao *et al*., 2015; Bhatt *et al*., 2015; Olajire *et al*., 2015; Ghaedi *et al*., 2015; Tiwari *et al*., 2015)

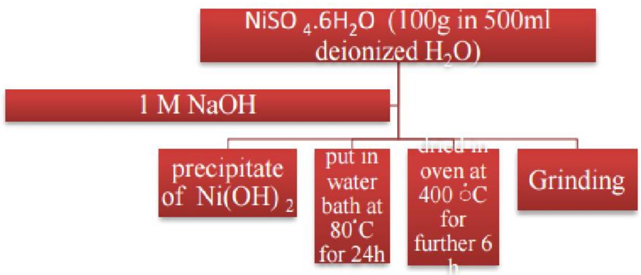

Figure 1. Schematic representation of co precipitation method of NiO nano composites

SURFACE MORPHOLOGY OF NICKEL OXIDE NANO PARTICLES

The surface morphology of amalgamated Nano composite was examined by FTIR and SEM techniques.

FTIR Analysis

The FTIR spectra of NiO nanoparticles, which revealed several substantial absorption peaks. The broad absorption band in the region of 550–790 cm^{-1} is allocated to Ni–O stretching vibration mode; the broadness of the absorption band specifies that the NiO powders are nano crystals. The size of analyte used in this research was much less than the bulks form NiO, so that NiO nanoparticles had its IR peak of Ni–O stretching vibration. Besides the Ni–O vibration, it might be comprehended from Figure 5 that the broad absorption band centered at 3990 cm^{-1} is attributable to the band O–H stretching vibrations and the fragile band near 1710 cm^{-1} is assigned to H–O–H bending vibrations mode were also existing due to the adsorption of water in air when FTIR sample disks were primed in an open air. These interpretations provided the confirmation to the effect of hydration in the structure. Temporarily, it inferred the presence of hydroxyl in the antecedent, and the broad absorption around 900 cm^{-1} is assigned to the band stretching vibrations. The serrated absorption bands in the region of 950–1400 cm^{-1} are allocated to the O–C=O symmetric and asymmetric stretching vibrations and the C–O stretching vibration, but the intensity of the band has deteriorated, which specified that the ultrafine powers inclined to strong physically absorption to H_2O and CO_2. (Su *et al*., 2015; Rahman and Sathasivam, 2015; Zhu *et al*., 2015; Zhou *et al*., 2015; Hammud *et al*., 2015; Mahdavi *et al*., 2015; Wang *et al*., 2015)

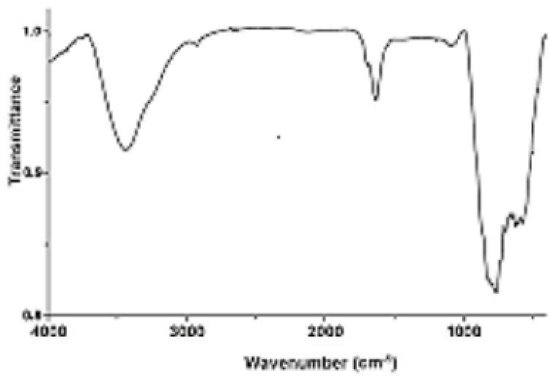

Figure 2. FTIR Spectrum of NiO nanoparticles

Scanning electron microscopy (SEM) Analysis

The surface morphology of synthesized NiO Nano composites was premeditated by SEM technique. It was pragmatic that the NiO Nano particles are approximately spherical with the diameter varying between 20 to 180nm. The empty sites present on the surface of NiO provide active sites for the adsorption of dye molecules. After adsorption empty spaces were filled by dye molecules that were adsorbed on the surface of NiO which looks as presented in the below figure. (Wang *et al*., 2015)

Batch Adsorption Experiments

The removals of dye CR was carried out by using NiO nano particles respectively. Adsorption experiments were headed under the optimized amount of adsorbent, shaking time, and concentration by adopting batch method.

Optimization of Adsorbent Dosage

All sorption experiments were carried out by developing the model system having 50ml of dye solution. The amount of nanoparticles varied from 0.01g to 0.1g.

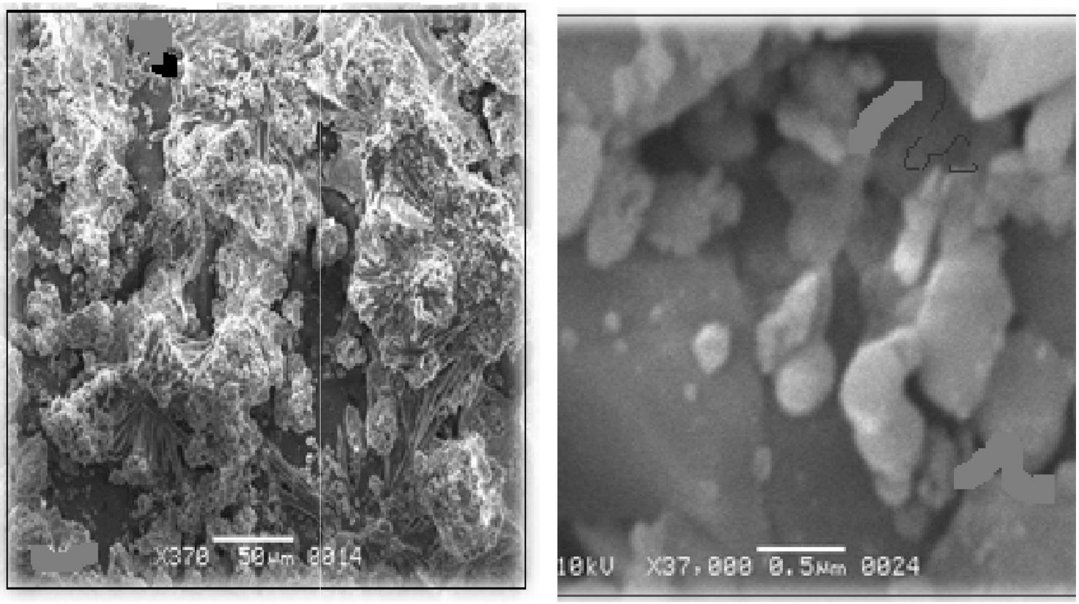

Figure 3. SEM image of NiO Nano composite before (size of nps are 58 micrometer) and after 91 Adsorption (size of nps are 0.5 micrometer)

Table 1. Optimization of Amount for the Removal of CR Dye by Using NiO Nanoparticles

S. No.	Amount of Adsorbent (g)	Equilibrium Concentration Ce (M)	% Removal	K_D (M)
01	0.010	3.487E-05	61.14575214	654.17
02	0.030	3.789E-05	66.44583009	601.99
03	0.050	4.098E-05	71.86282151	556.62
04	0.070	4.618E-05	80.98207327	493.94
05	0.090	5.151E-05	90.33515199	442.80

Table 2. Optimization of Stay Time for the Removal of MGO Dye by Using CdO Nanoparticles

S. No.	Amount of Adsorbent (g)	Time (min)	Equilibrium Concentration Ce (M)	% Removal	K_D (M)
01	0.09	15.00	3.07E-05	54.52	218.07
02	0.09	30.00	3.66E-05	64.89	259.57
03	0.09	45.00	3.93E-05	69.78	279.13
04	0.09	60.00	3.26E-05	57.79	231.16
05	0.09	90.00	3.48E-05	61.85	247.42
06	0.09	120.0	3.32E-05	58.86	235.42
07	0.09	180.0	4.05E-05	71.87	287.50
08	0.09	240.0	3.79E-05	67.30	269.19

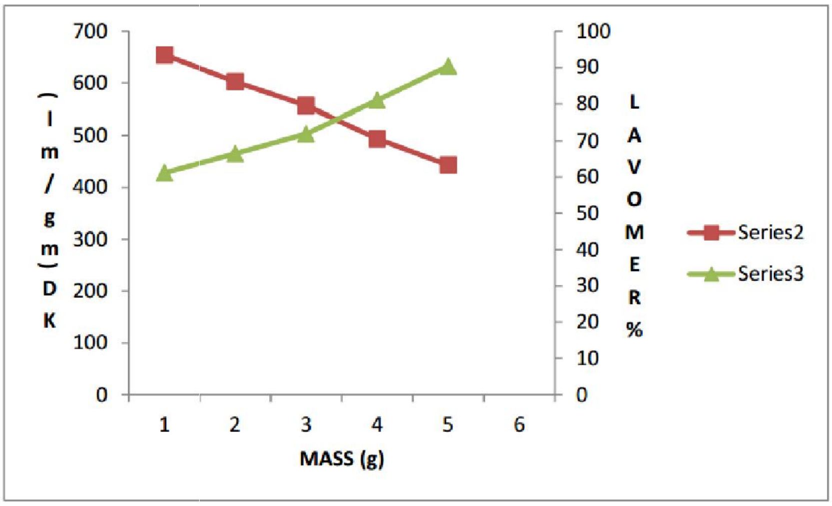

Figure 4. Optimization of Amount of NiO-CR system

All the flasks were placed in shaking incubator for 30min at 200rpm and the temperature was adjusted at 30°C=303K. The analyte of each flask were filtered with filter paper and absorbance was sedate at 591nm using Spectrophotometer (Mahmoodi *et al*., 2014). The optimum dose of NiO nanoparticles were selected by calculating % removal values.

Optimization of Shaking Time

For the determination of optimum shaking time, 50ml of dye solution was taken in shaking flask and the optimized amount of NiO nanoparticles were added in all flasks. The shaking time was varied from 15 to 240 min for CR. After specific interval of time content of each flask was filtered, and the absorbance of the filtrate was recorded using UV-visible Spectrophotometer (Ho, 2014). The optimum shaking time of adsorbent was determined by finding K_D and % removal values.

Optimization of Concentration

Several working standard of dye solutions were prepared by varying the concentrations of 50ml of each solution was taken in separate flask and optimized amount of adsorbent was added in respective flask and kept them in shaking incubator by keeping optimized time at 303K temperature. After optimized time the contents were filtered out and absorbance of each the content was measured at their respective λ_{max}. The optimum range of concentration CR dye was selected for further studies. (Tiwari *et al*., 2014)

Effect of Amount of Adsorbent

The % removal of dye onto the adsorbent as a function of adsorbent prescription is shown in Figure 3. It was detected that the adsorption effectiveness increased from 61 - 90% for NiO. As the adsorbent dose increases from 0.01 to 0.09g the amount of adsorbent was proliferated due to the availability of active sites. Hence percentage removal was also revivals (Ho, 2014).

Effect of Contact Time

Adsorption equilibrium was succeeded after definite time interlude. The progression adsorption of dye on the surface of adsorbent was amplified by the intensification in contact time and removal success reached to an optimum value when the equilibrium between both adsorbate and adsorbent was done. The maximum adsorption capacity of CR for NiO was found to be 72% approximately at 180min as shown in Figure 4.

Adsorption isotherms

Langmuir Adsorption Isotherm

The Langmiur isotherm espouses monolayer adsorption on a homogeneous surface with a limited number of adsorption facts. The monolayer adsorption can be merely defined by Langmuir adsorption isotherm. The well-known Langmuir equation is inscribed as:

$$C_e/X/m = 1/KV_m + C_e/V_m$$

Where, C_e is the equilibrium concentration (mol/dm^3), X/m is the amount adsorbed at equilibrium (mol/g) and Vm (mol/g) and K (dm^3/mol) is Langmuir constants accompanying to monolayer capacity and adsorption coefficient respectively . A straight line was assimilated by plotting C_e/X/m versus C_e. From the slopes and intercepts the values of constants K and V_m were premeditated. The adsorption of Congo Red (CR) was examined at dissimilar temperatures (Wang *et al*., 2014; Dutta *et al*., 2014; Ho, 2014; Krishni *et al*., 2014). In the case of NiO-Congo red dye system there were risen in the values of K with the upsurged in temperature from 303K to 313K .It proved the strong adsorbate-adsorbent interaction at higher temperatures. It also exposed that the adsorption magnetism of dye was increased with the risen in temperature so adsorption is inspiring at high temperatures. The monolayer capacity (V_m), for congo red – NiO system customs onto the homogenous adsorbent surface. The values of K were positive offered that they were tracked the Langmuir adsorption isotherm. The values of R^2 are 0.9428, 0.9525, 0.9476 achieved at 303K, 313K and 318K respectively shows that strong adsorption ensues according to Langmuir adsorption isotherm and monolayer customs onto the homogenous adsorbent surface. (Xing *et al*., 2014)

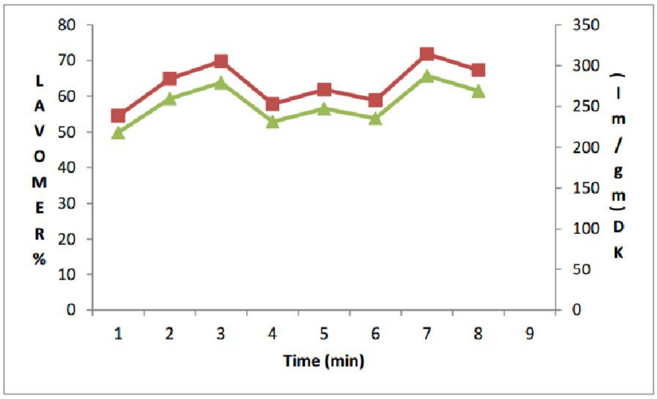

Figure 5. Optimization of Stay Time of NiO-CR system

Freundlich Adsorption Isotherm

The Freundlich isotherm was specified by using the consequent equation:

$$\text{LogX/m} = \log K + 1/n \log C_e$$

Where, X/m is the amount adsorbed per unit mass of the adsorbent (mol/g), C_e is the equilibrium concentration (mol/dm^3) and 1/n and K are Freundlich constants. Figure epitomized the Freundlich plots which were accomplished at various temperatures. Values of K and n were calculated from the slopes and intercepts of their relevant plots were recorded in Tables. The constant K relayed to the degree of adsorption of the adsorbent/adsorbate system. While "n" provides the rough approximation of intensity of the adsorption. (Mishra *et al*., 2014) The increase in the values of K with the rise in temperature for Congo Red-metal titanate system reveals that adsorption attraction of dye is favorable at higher temperatures. In NiO Nano particles – Congo red system values of K constants were increased by increased in temperatures and showed that adsorption of dye was auspicious at high temperature. The upsurged in the values of

K with the increased in temperature shows that there is high interaction with the adsorbent as shown in tables and figure. The values of R^2 were 0.928, 0.9582, 0.6285 and 0.8319 at temperatures 303K, 308K, 313K and 318 K respectively, shown that the adsorption tracked Freundlich isotherm. R^2 shown that Freundlich isotherm and indicated creation of multilayer on the surface of adsorbent. The date fitted sound in Freundlich isotherm with “N” values of 1.0535, 3.5014, 2.7112 and 0.9785 at temperatures 303K, 308K, 313K and 318 K respectively. (Mahmoodi *et al*., 2014)

Dubinin Redushkevish Isotherm

The adsorption data were also formfitting on Dubinin-Radushkevish, (D-R) isotherm is epitomized as:

$$\textbf{Ln X/m} = \ln X_m - K\,\epsilon^2$$

$$\epsilon = RT\ln(1+1/C_e)$$

Where, X_m is the monolayer capacity of adsorbent, K is a constant associated to adsorption energy, ϵ is adsorption potential, R is a gas constant, T is absolute temperature, X/m and Ce have customary meanings.

The D-R plots of ln (X/m) versus ϵ^2 were achieved at various temperatures are shown in Figs. Values of X_m and K were computed from the intercept and slopes of the corresponding plots and the mean free energy of sorption (E_s) was calculated from K by using the equation:

$$E_s = (-2K)^{-1/2}$$

Table shows the value of Es for CR-metal titanate systems. It was decreases with the increase in temperature, but in few cases CR-metal titanate system, the values of Es decreases as shown in table (Mahmoodi *et al*., 2014).

Temkin Isotherm

This isotherm comprises a factor that explicitly taking into the account of adsorbent–adsorbate interactions. By flouting the extremely low and large value of concentrations, the model adopts that heat of adsorption (function of temperature) of all molecules in the layer could decrease linearly rather than logarithmic with treatment. As implied in the equation, its derivation is characterized by a uniform dissemination of binding energies (up to some maximum binding energy) was carried out by plotting the quantity sorbed qe against lnCe and the constants were resolute from the slope and intercept. The model is given by the following equations:

$$q_e = RT/b\ \ln(A_T C_e)$$

$$qe = RT/b_T \ln A_T + (RT/b)\ln C_e$$

A_T =Temkin isotherm equilibrium binding constant (L/g)
b_T = Temkin isotherm constant
R= universal gas constant (8.314J/mol/K)
T= Temperature at 298K.
B = Constant related to heat of sorption (J/mol)

From the Temkin plot shown in fig. the following values were estimated which is an indication of the heat of sorption indicating a physical adsorption progression. (Ofomaja *et al*., 2014; Mahmoodi *et al*., 2014; Ghaedi *et al*., 2014; Mahmoodi, 2014)

Thermodynamic parameter

Thermodynamic parameters of an adsorption progression are necessary to conclude whether the process is spontaneous or not. Gibb’s free energy change, Δ*G*°, is the fundamental standard of spontaneity. Reactions occur spontaneously at a given temperature if Δ*G*° is a negative value. The thermodynamic parameters like enthalpy ΔH^0, entropy ΔS^0 and Gibbs free energy ΔG^0 were premeditated by using the following equations:

$$\Delta G^0 = \Delta H^0 - T\Delta S^0$$

$$\ln k_D = \Delta S^0/R - \Delta H^0/RT$$

$$\Delta G^0 = -RT\ \ln k_D$$

Where R is the gas constant, T is the absolute temperature, K_D is equilibrium constant. The values of ΔH^0 and ΔS^0 were achieved from the slopes and intercepts of the Van’t Hoff plot of Ln K_D versus 1/T (Mahmoodi *et al*., 2014; Hu *et al*., 2014; Hu *et al*., 2014). The values of ΔH^0 and ΔS^0 were calculated from the slope and intercept of the linear variation of ln K_D with the reciprocal of temperature (1/T) are presented in figures and in Tables. Negative values of Δ*G*° confirm the feasibility of the method and the spontaneous nature of adsorption with a high preference of dye. The decrease in the negative value of Δ*G*° with an increase in temperature indicates that the adsorption process of dye becomes more auspicious at higher temperatures The negative values of ΔG° for dye indicates the spontaneous nature of the adsorption procedure at different temperature. The negative values of Δ*G*° and the positive value of Δ*H*° of NiO nano particles indicate the spontaneous nature of adsorption with a high preference of dye. Entropy has been well-defined as the degree of chaos of a system. The positive value of ΔS° recommends that some structural changes occur on the adsorbent, and the randomness at the solid/liquid interface in the adsorption system rises during the adsorption progression The positive value of ΔH° for NiO nano particles which approves the endothermic nature because there is a large upsurge of translational mobility on the surface. The dye system confirms positive values of ΔS^0 describe the randomness and negative values of ΔS^0 indicate some deviation in the adsorption system. The positive values of ΔS^0 reveal the increase randomness of the solid-solution interface and recommended some structural changes in both adsorbate and adsorbent during the adsorption method.

Adsorption Kinetics

The study of adsorption kinetics provides the information regarding the rate of adsorption and feasibility of adsorption process. The experimental data were applied to examine the kinetics by Lagergren’s pseudo first order and Ho-Mckay’s pseudo-second order models { as represented:

Table 3. % Removal of MGO by Using NiO nps at Different Temperatures

Dye	Ci (M)	% REMOVAL			
		303K	308K	313K	318K
Congo red dye	5.5	71.87	77.48	80.81	69.97
	4.24	70.61	77.91	83.53	70.93
	3.5	70.08	76.56	83.05	72.05
	2.55	68.09	73.99	84.61	72.42
	1.56	69.12	70.48	85.76	71.71
	0.445	68.98	63.27	80.57	76.48

Table 4. Langmiur Parameters of Adsorption of CR Dye on NiO nps

LANGMUIR PARAMETER FOR NiO-CR SYSTEM							
S. No.	Temperature K	Intercept 1/K Vm	Slope 1/Vm	Constant K_L	Constant Vm	R^2	R_L
01	303	0.1577	1248.6	7917.564	8.0089E-04	0.4354	1.44E-08
02	308	0.0732	7951.8	108631.14	1.2575E-04	0.9428	-6.89E-08
03	313	0.1473	3817.6	25917.175	2.61944E-4	0.9525	1.77E-06
04	318	0.025	637.27	2549.08	1.569E-3	0.9476	3.44E-07

Table 5. Freundlich Parameters of Adsorption of MGO Dyes on NiO nps

FREUNDLICH PARAMETER FOR NiO-CR SYSTEM							
S. No.	Temperature K		Intercept log k	Slope 1/n	Constant K_F	Constant N	R^2
01	303	0.9719		0.9492	9.3734	1.0535	0.9283
02	308	- 1.15		0.2856	14.1253	3.5014	0.9582
03	313	-0.5935		0.3687	0.2526	2.7112	0.6285
04	318	2.4494		1.02471	281.44	0.9758	0.8319

Table 6. Dubinin Radushkevich (DR) Parameters for MGO Dye on NiO nps

D-R PARAMETER FOR $AgTiO_3$-CR SYSTEM							
S. No.	**Temperature K**	**Intercept lnX/m**	**Slope (Neg) K**	**Constant X/m**	**Constant (K)'**	**Free energy Es(KJ/mol)**	**R^2**
01	298	-6.442377	-5.52444E-10	1.59E-03	5.52E-10	3.01E+04	0.00304
02	303	0.76475	-1.00362E-08	2.15E+00	1.00E-08	7.06E+03	0.18920
03	308	-0.793645	-6.6388E-09	4.52E-01	6.64E-09	8.68E+03	0.47638
04	313	-0.3444949	-6.56169E-09	7.09E-01	6.56E-09	8.73E+03	0.31422

Table 7. Tempkin Parameters for CR Dye on NiO nps

TEMPKIN PARAMETER FOR NiO-CR SYSTEM					
Temperature K	Intercept B lnAT	Slope B	Constant AT	Constant bT	R^2
298	-5.724E-03	-5.918E-04	1.458E+04	-4.174E+06	0.044999
303	-2.333E-03	-2.821E-04	3.912E+03	-8.995E+06	0.056877
308	1.623E-02	1.240E-03	7.628E+05	2.113E+06	0.321912
313	1.129E-02	8.433E-04	1.43E+06	3.039E+06	0.098157

Table 8. Thermodynamic Parameters for the Adsorption of MGO on NiO nps

Sample	T (K)	ΔG° (KJmol-1)	ΔH° (KJmol-1)	ΔS° (KJmol-1)	Ln k	1/T
NiO NP	303	-14528.131	2593.146	39.98788	8.9768	0.0034
	308	-14383.087			9.2931	0.0033
	313	-14537.753			10.16266	0.0032
	318	-14337.910			7.8434	0.0032

The values of rate constant and R^2 for the MGO sorption on CdO systems are represented in above table. The results show that the system follows the pseudo second order kinetics. Where k_{id} is the intra-particle diffusion rate constant which was obtained from the slope of the linearized plot of qt verses $t_{1/2}$. The intercept gives an idea of the thickness of the boundary layer i.e. the larger the intercept; the greater will be the boundary layer effect. The positive values of slope shows controlled adsorption process (Mahmoodi, 2014; Ho, 2014; Atiya Firdous and Uzma Hameed, 2016).

RESULTS AND DISCUSSION

The literature reviewed shown that there has been a high proliferation in outcome and utilization of organic pollutants in last few years subsequent in a big threat of contamination.

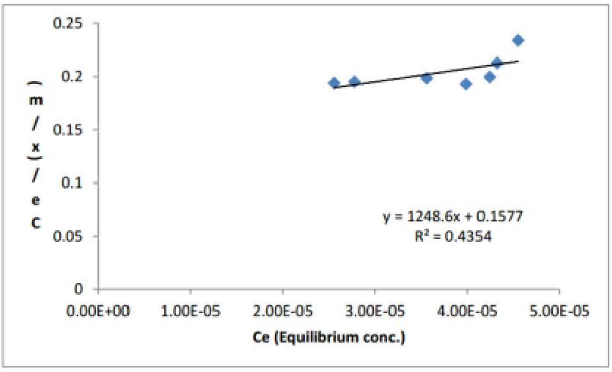

Figure 6. Optimization of Langmuir parameters at temperature 303K of NiO Nano particles

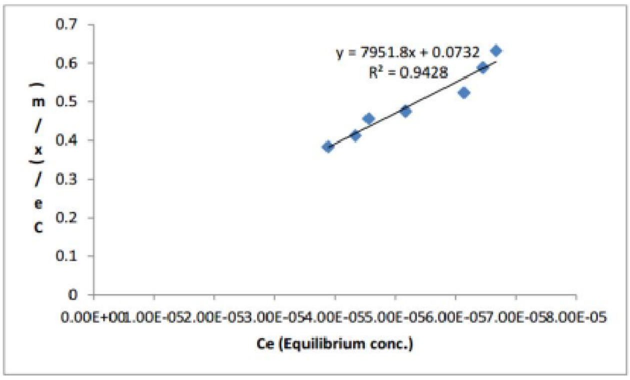

Figure 7. Optimization of Langmuir parameters at temperature 308K of NiO Nano particles

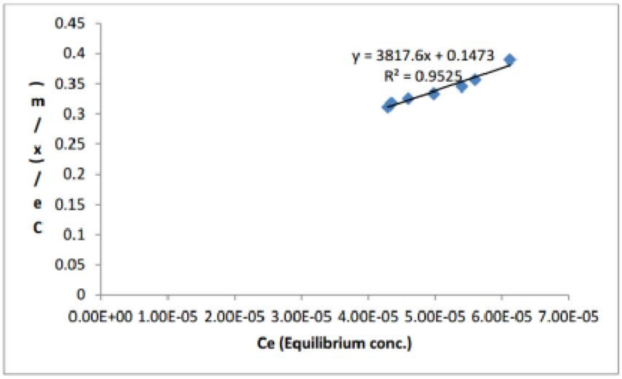

Figure 8. Optimization of Langmuir parameters at temperature 313K of NiO Nano particles

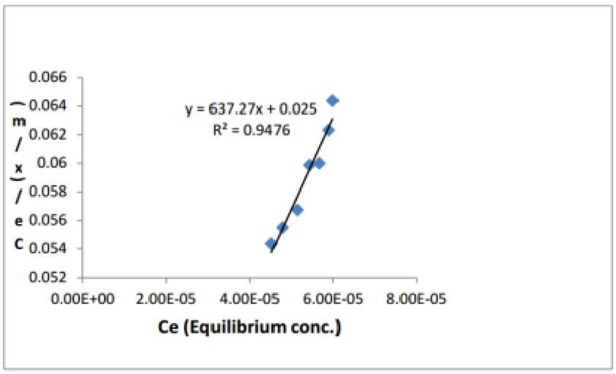

Figure 9. Optimization of Langmuir parameters at temperature 318K of NiO Nano particles

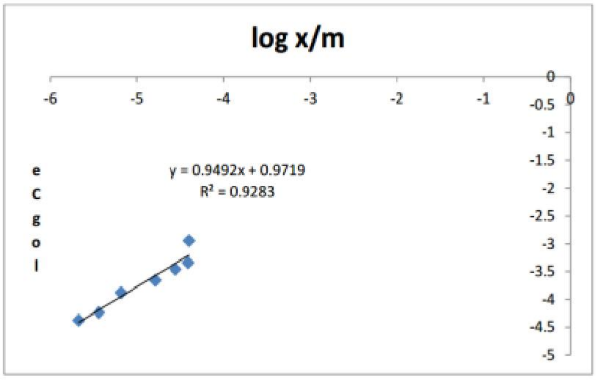

Figure 10. Optimization of Freundlich parameters at temperature 303K of NiO Nano particles

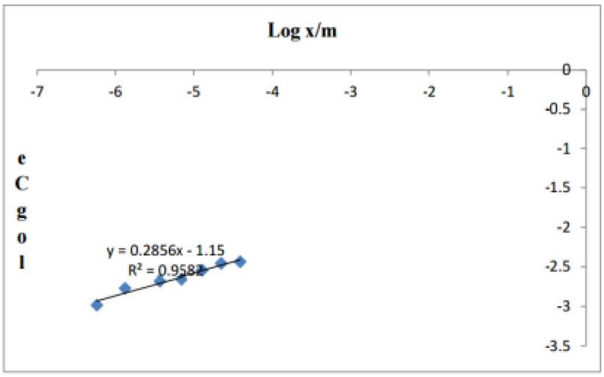

Figure 11. Optimization of Freundlich parameters at temperature 308K of NiO Nano particles

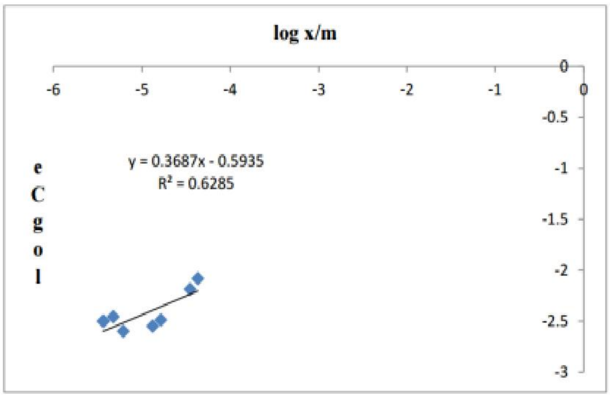

Figure 12. Optimization of Freundlich parameters at temperature 313K of NiO Nano particles

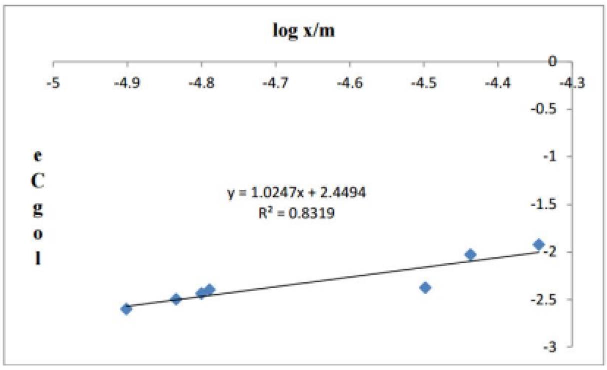

Figure 13. Optimization of Freundlich parameters at temperature 318K of NiO Nano particles

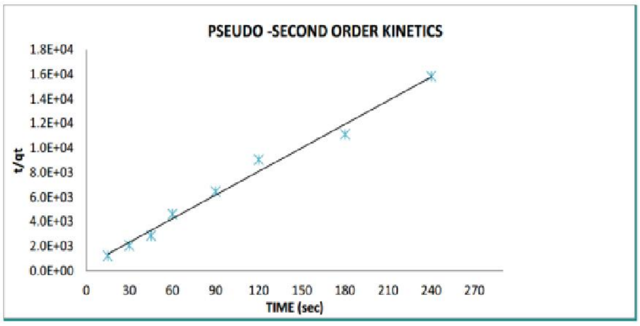

Figure 14. Kinetics of NiO nano particles

Proficient techniques for the elimination of highly toxic organic compounds from water and wastewater have drawn substantial concern. Adsorption is recognized as an operative and low cost technique for the elimination of organic toxins from water and wastewater, and produce high-quality treated run-off. This research emphasized the removal of organic pollutants using adsorption technique with synthetic adsorbents. Nano particle NiO was synthesized by a stated method. The characterization of synthesized adsorbent was carried out by Fourier Transformed Infrared Spectroscopy and Scanning Electron Microscopy. The adsorption of Congo red dye was considered by using NiO nano particles. The optimum circumstances for the adsorption of dye were resolute. The experimental data showed the adsorption followed pseudo second order kinetics. The investigational data form fitted in Freundlich and Langmuir isotherms. To conclude which model to use to describe the adsorption isotherms the experimental data were analyzed using linearized forms of two, the widespread-used, Langmuir and Freundlich models. As a robust equation, Freundlich isotherm fitted approximately all experimental adsorption data, and was particularly excellent for highly heterogeneous adsorbents. The negative ΔG^o value indicates the spontaneity of adsorption of NiO nano particles. The maximum removal of dye by experimental results was found and i can conclude that this specific method can be employed on industrial scale for waste minimization. This study offers a lot of promising benefits in the future. It is a simple and highly economic technology than all other technologies since it has very good potential of reducing color. Dyes which pollute large part of textile effluent can be transformed into colorless and non-toxic compounds by this technique. Thus, this method may be applicable for industrial purposes for improvement in quality of wastewater of textile industries and many others.

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