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Adsorption removal of carcinogenic acid violet19 dye from aqueous solution by polyaniline-Fe_2O_3 magnetic nano-composite

Manohar R. Patil and V.S. Shrivastava*
Nano-Chemistry Research Laboratory, G.T.P.College, Nandurbar-425412 (India)

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Email: profmanoharpatil@gmail.com , drvinod_shrivastava@yahoo.com

Abstract

The present work deals with the development of a novel method for the removal of dyes from aqueous solution by using Polyaniline (PANI)-Fe_2O_3 nano-composite. It is successfully synthesised in situ through self polymerisation of monomer aniline. Adsorptive removal studies are carried out for water-soluble carcinogenic acid violet 19 (acid fuchsine) dye by using PANI-Fe_2O_3 nano-composite in aqueous solution. Different parameters like dose of adsorbent, contact time and pH have been studied to optimise reaction condition. It is observed that adsorptive removal by PANI-Fe_2O_3 nano-composite is more effective and faster mode of removing Acid violet 19 dye from aqueous solution than work done before. The optimum conditions for the removal of the dye are initial concentration 20 mg lt^{-1}, adsorbent dose 10 gm lt^{-1}, pH 8. The adsorption capacity is found 7.7 mg g^{-1}. The EDS technique gives elemental composition of synthesised PANI-Fe_2O_3. The SEM and XRD studies are carried for morphological feature characteristics of PANI-Fe_2O_3 nano-composite. Besides the above kinetics and isotherm studies have also been carried out.

Keywords- Adsorptive removal, Acid violet 19 dye, PANI-Fe_2O_3 nano-composites, SEM, EDS, XRD.

1. Introduction

Environmental pollution due to industrial effluent is a major concern because of its toxicity and threats for human beings. The environmental pollution control is one of the prime concerns of the society in todays context. The presence of these dyes in water even at very low concentration is highly visible and undesirable. A wide range of methods have been developed for the removal of synthetic dyes from water and wastewater to decrease its impact on environment. Over 70,000 tons of approximately 10,000 types of dyes and pigments are produced annually world wide of which about 20 – 30% are wasted in industrial effluents during the textile dyeing and finishing processes [1]**.** Adsorption is one of the method, which is obtaining more attention because of its easy operations and versatility.

Adsorption is an affordable and effective technique for the removal of dyes and colored pollutants from wastewater [2]. Nano-adsorbents can be readily integrated into existing treatment processes in slurry reactors. Applied in the powder form, nano-adsorbents in slurry reactors can be highly efficient since all surfaces of the adsorbents are utilized and the mixing greatly facilitates the mass transfer [3]. Removal of hazardous, carcinogenic compounds from industrial wastewater is one of the growing needs in the present time. Many dyes and pigments are toxic in nature, with carcinogenic and mutagenic effects [4]. Use of cellulose based waste materials for adsorption of dyes from aqueous solution [5]. Activated carbon is the most widely used adsorbent for the removal of color from textile effluents. It is so because it has a high capacity for organic matter, but its use is limited due to its high cost [6]. Removal of textile dyes from aqueous solution with eco-friendly bio-adsorbent [7], a low cost agro waste material [8], Adsorption of dye on to rice husk [9],Adsorption of dye on shale oil ash [10], have been searched. Use of fibrous mass is a recent method for the removal of hazardous and carcinogenic effect having dyes [11]. Acid dyes are organic sulphonic acids , the commercially available forms are usually sodium salts, which exhibit good water solubility.[12]. Several researchers have also tried for the treatment of various dye wastewater by adsorption over low cost materials [13]. Adsorption of hazardous dye on low cost adsorbent [14-18].

In recent years, composites containing PANI and magnetic oxides exhibiting different nanostructures, such as nano-tubes, nano-rods or core shell nano-structures, have been extensively studied [19-22]. Clays can be modified to improve their sorption ability, one of the modification method is coating of magnetic nano-particles

[23,24]. Many authors have been used magnetic particle in nano-scale [25]. Fast removal and recovery of congo-red by modified iron oxide magnetic nano-particles [26].

The present work of investigation is a novel, simple and fast method for removal and recovery of Acid violet 19 dye by conducting PANI-Fe_2O_3 nano-composites as adsorbent. Adsorption experiment is carried out and also studied the adsorption kinetics for adsorption of Acid violet 19 on PANI-Fe_2O_3 nano-composites.

2. **Experimental**;

2.1. Materials and methods

Acid violet 19, $Fe(No_3)_39H_2O$, FeS, NH_4OH, monomer Aniline, distilled Water, Ammonium per –sulphate $[(NH_4)_2S_2O_8]$. The water soluble Acid violet 19 dye which has M.F.$C_{20}H_{17}N_3O_9S_3Na_2$, M.W. 585.54 gm and PANI-Fe_2O_3 nano-composite is used as adsorbent. All chemicals and reagents were of analytical grade purity. The structure of dye presented in the fig-1.The stock solution 50 mg/lt of acid violet 19 dye is prepared in double distilled water. In 50 ml of dye solution of the desired concentration, of different adsorbent dose is added and stirred with magnetic stirrer. At specific time interval suitable aliquot of the sample is withdrawn and analyse after centrifugation. The changes in dye concentration are determined by UV-Visible double beam spectro-photometer (systronics model-2203) at λ max 545 nm in our laboratory.

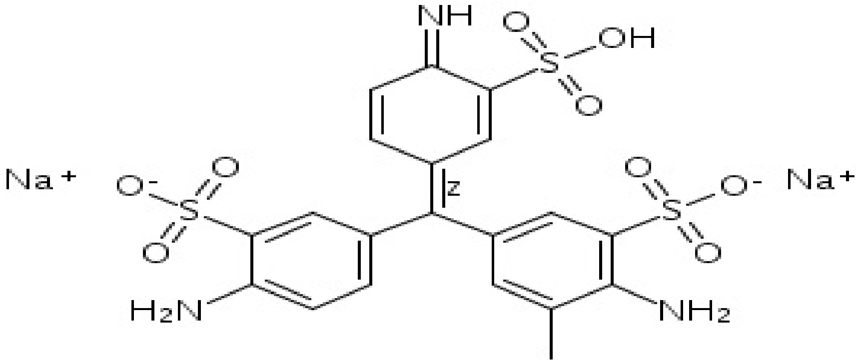


Fig-1. Structure of acid violet 19 dye

2.2. Preparation of Ferric Oxide nanoparticles

The 100 ml solution of Ferric nitrate $[Fe(NO_3)_39H_2O]$(0.1M) was prepared in distilled water, it was then gelated by using 800 ml of monohydrated citric acid solution (0.1M) as ligand molecules. The Ferric nitrate solution was added to the citric acid solution drop-wise with vigorous stirring. The solution was then heated to a temperature of $80C^0$, while maintaining vigorous stirring until the gel was formed and the contained water was evaporated. Then nano-particles of Fe_2O_3 was yielded.

2.3. Preparation of PANI-Fe_2O_3 nano-composite

The solution of Fe_2O_3 nano-particle, monomer aniline, and ammonium per-sulphate ($(NH_4)_2S_2O_8$) was prepared in distilled water with vigorous stirring at R.T. The amount of Fe_2O_3 & monomer aniline was taken in 1:2 ratio.The pH value was controlled during the entire experiment to pH-11. A black precipitate of PANI-Fe_2O_3 was observed after 10 hour. The resulting polymer nano-composite was poured into water and filtered. Each wash step is carried out until the filtrate become clear and colourless. Finally, the polymer composite is washed with distilled water, ethanol, then dried.

3. Results and Discussion

3.1. Characterisation and Analysis:

3.1.1. SEM Analysis-

Scanning electron microscopy is widely used to study the morphological features and surface characteristics of adsorbent materials. The PANI-Fe_2O_3 nano-composites is analysed by SEM before fig-2(a) and after adsorption of Acid violet 19 dye as shown in the fig-2(b). It show SEM micrographs of PANI-Fe_2O_3 and PANI-Fe_2O_3 dyed by Acid violet 19.They shows surface texture and porosity of PANI-Fe_2O_3.The PANI-Fe_2O_3 has heterogeneous surface, micro-pores and meso-pores as seen from its surface micrographs.

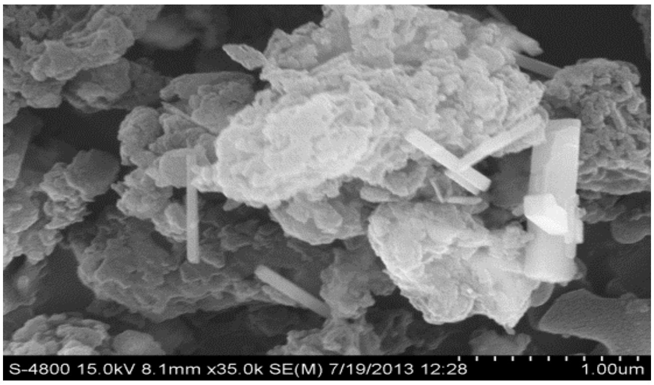


Fig-2(a). SEM images of Prepared PANI- Fe_2O_3 nano-composites.

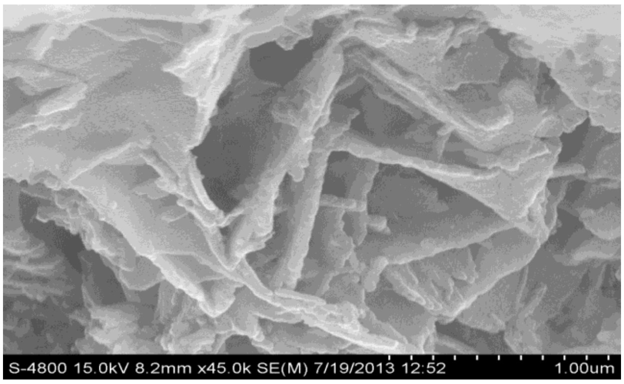
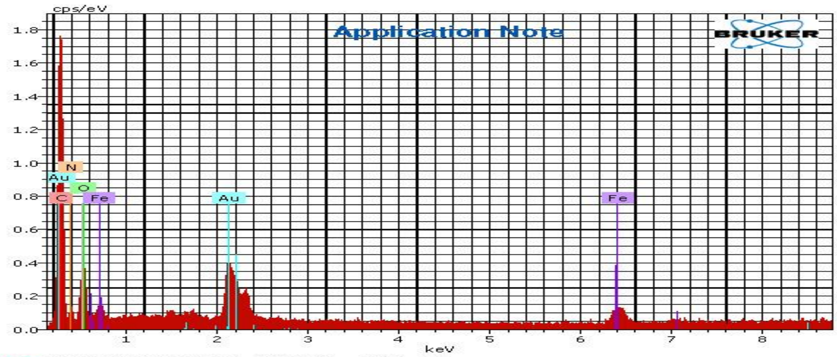


Fig-2(b). SEM images of adsorption of acid violet 19 dye on PANI-Fe_2O_3 nano-composites.

3.1.2. Electron Dispersive X-Ray Spectroscopy(EDS) Analysis-

Interaction of electron beam with a sample target produces a variety of emissions. An energy-dispersive (EDS) detector is used to separate the characteristic x-rays of different elements into an energy spectrum, and EDS system software is used to analyze the energy spectrum in order to determine the abundance of specific elements. EDS can be used to find the chemical composition of materials down to a spot size of a few microns, and to create element composition maps over a much broader raster area. Together, these capabilities provide fundamental compositional information for a wide variety of materials. From the analysis, comes to know that PANI-Fe_2O_3 nano-composite consist of exact elemental composition of specific element like Fe, O, C, N etc. is as shown in the(fig.3).The observed elemental composition is Fe=2.39%,O=16.68%,C=67%,N=12.21%.As PANI-Fe_2O_3 is conducting material therefore it needs to coat with gold(Au) metal.



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1309    Date:7/19/2013 12:20:13 PM     HV:15.0kV       Puls th.:0.99kcps
El AN  Series   unn. C norm. C Atom. C Error (1 Sigma)
                [wt.%]  [wt.%]  [at.%]          [wt.%]
-----------------------------------------------------
C   6  K-series  20.05   46.92   67.00            2.84
N   7  K-series   4.26    9.97   12.21            1.11
O   8  K-series   6.65   15.56   16.68            1.24
Fe 26  K-series   3.32    7.78    2.39            0.16
Au 79  M-series   8.45   19.77    1.72            0.38
-----------------------------------------------------
         Total:  42.73  100.00  100.00
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Spectrum:  1309
El AN  Series   unn. C norm. C Atom. C Error (1 Sigma)
                [wt.%]  [wt.%]  [at.%]          [wt.%]
-----------------------------------------------------
C   6  K-series  20.05   46.92   67.00            2.84
N   7  K-series   4.26    9.97   12.21            1.11
O   8  K-series   6.65   15.56   16.68            1.24
Fe 26  K-series   3.32    7.78    2.39            0.16
Au 79  M-series   8.45   19.77    1.72            0.38
```

Fig- 3. EDS image of gold coated (Au) PANI-Fe_2O_3 nano-composites

3.1.3. XRD Analysis-

The XRD diagram of PANI-Fe_2O_3 is as shown in Fig-4.It shows the main peak spectrum 2θ of 33^0 and 2^0 peak of 2θ of 35^0 and 63^0 respectively. The high intensity of peaks indicates the crystalline nature of PANI-Fe_2O_3. By Scherer, formula is 20 nm estimated the average crystalline size of PANI-Fe_2O_3 particles.

3.2. Parametric studies-

The adsorptive removal of Acid violet 19 is studied at λ max 545 nm. The optimum condition for removal of dyes is 20 mg/ Lt, pH 8, PANI-Fe_2O_3 10gm\lt. The results obtained during this study are as shown in the figs (5-7).

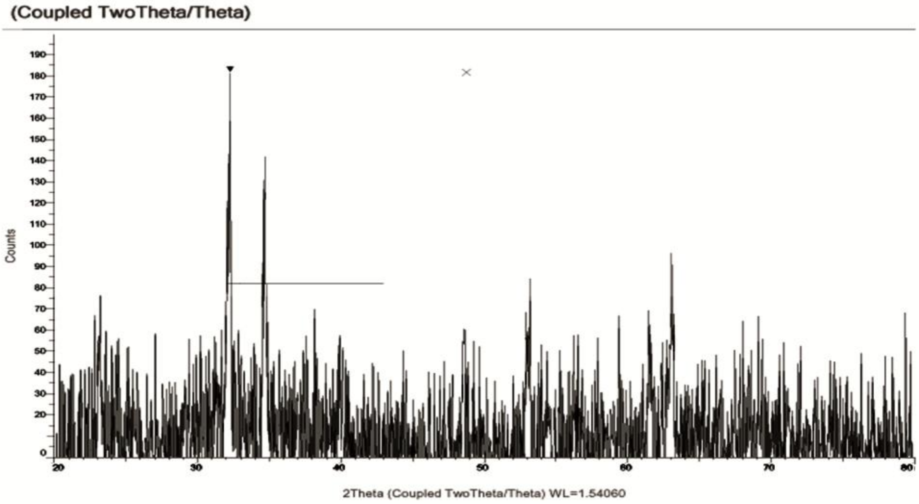

Fig-4 the XRD diagram of prepared PANI-Fe_2O_3.

3.2.1. Effect of adsorbent dose-

The effect of adsorbent dose on the removal of acid violet 19 dye is investigated. The % removal of acid violet 19 dye by PANI-Fe_2O_3 nano-composite at different adsorbent doses 2 to 10gm/lt for 20 to 80 mg/lt of dye conc. was studied as shown in the (fig-5). Adsorptive removal of Acid violet 19 increases rapidly from 55-98.5% with an increasing amount from 2-10gm/lt of PANI-Fe_2O_3 nano-composite. As the number of active sites for the adsorption increases, removal of acid violet 19 also increases is as shown in the (fig 5).It is also observed that, as the conc. of dye increases from 20 -80 mg/lt, % removal of dye decreases from 98.5-90 % for adsorbent dose 10 gm/lt.

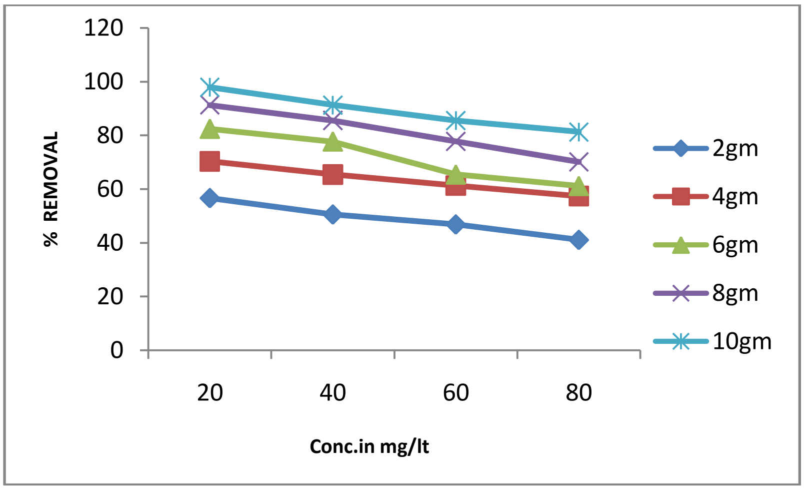

Fig-5: Effect of adsorbent dose on % removal of acid violet 19 dye for different initial dye conc. With contact time 90min,$_p$H 8.

3.2.2. Effect of $_p$H-

The adsorptive removal of dye was studied at different pH values as it is an important parameter for reaction taking place on the particular surface. The role of pH on the adsorptive removal of acid violet 19 was studied in the pH range 0-10 at dye concentration 20 mg/lit and PANI-Fe_2O_3 concentration 10gm\lt. It was observed that the rate of adsorption increases with an increase in pH up to 8 is as shown in the (fig-6). As the pH increases, no. of acid anions increased. These acid anions form a bond with PANI-Fe_2O_3 nano-composite. This adsorption is based on Intraparticle diffusion model. When the $_p$H increases onwards 8.5, the repulsion of the dye anions by negatively charged PANI-Fe_2O_3, therefore surface would result in reduction in efficiency of adsorption of Acid violet 19 dye. At low $_p$H acid anions of dye does not formed hence observad % removal of dye is minimum.

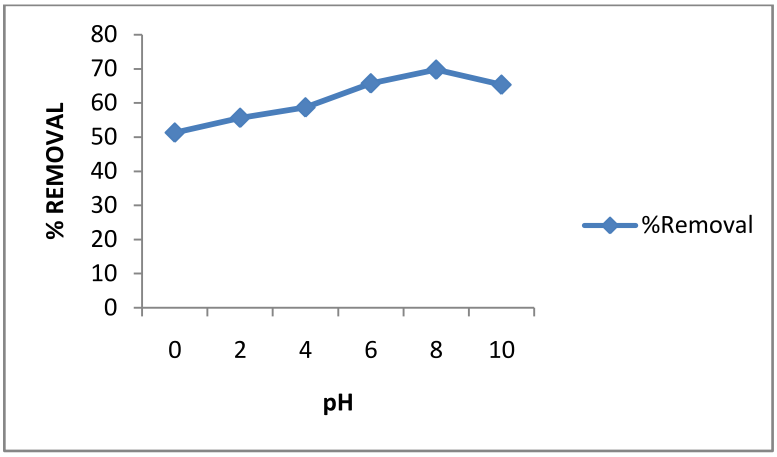

Fig 6. Effect of pH on removal of acid violet 19 dye by PANI-Fe_2O_3 adsorbent dose 10g/lt at 20mg/lt.

3.2.3. Effect of contact time-

The effect of contact time for the removal of acid violet 19 dye by PANI-Fe_2O_3 nano-composite is as shown in fig-7.It is observed that the dye is rapidly adsorbed in the first 40min up to 80% and then adsorption rate decreased gradually and reached equilibrium in about 90 min up to 98.5%. At the beginning adsorption rate is faster as the dye ions are adsorbed by the exterior surface of the PANI-Fe_2O_3 nano-composite. When the adsorption of the exterior surface reaches saturation, the ions exerted onto the pores of the adsorbent PANI-Fe_2O_3 and are adsorbed by the interior surface of particle. This phenomenon takes relatively long contact time.

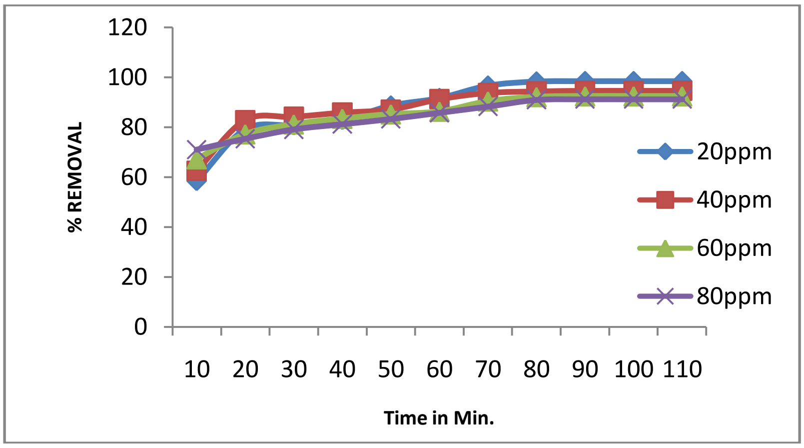

Fig-7. Effect of contact time of acid violet 19 on % removal adsorbent dose 10g\lt at pH 8 (where-1 ppm = 1mg/lt)

4. Adsorption kinetics study-

The adsorption kinetics gives the idea about mechanism of adsorption, from which efficiency of process estimated.

4.1. Pseudo 1st Order-

The integrated form of equation is

$$\log(qe - qt) = logqe - \left(\frac{k1}{2.303}\right)t \qquad (2)$$

Where q_e & qt are the amounts of dye adsorbed (mg/g) on PANI-Fe_2O_3 at equilibrium & at time t (min) respectively, while K_1 is the rate constant obtained from the slope of the plot log (qe-qt) Vs time is as shown in (fig-8&fig-9).The linear relationship of the plot for 20,40,60,80 mg/lt dye concentration indicates validity of equation. These calculated K_1 and correlation coefficient r^2 values are shown in Table 1.The correlation coefficient r^2 for the plots are >0.866,the calculated qe values from 1^{st} order kinetics plots are too small as compared to experimental qe values(as shown in Table 1).This shows that the Pseudo 1^{st} order kinetic model is not applicable to predict the adsorption kinetics of acid violet 19 on PANI-Fe_2O_3 nano-composite.

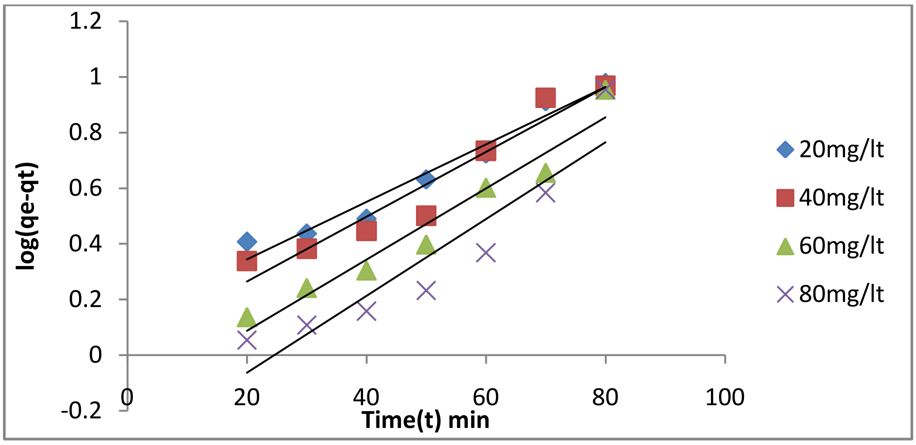

Fig-8. Pseudo 1st order kinetics of acid violet 19 dye with adsorbent(PANI-Fe_2O_3)dose10gm/ lt.

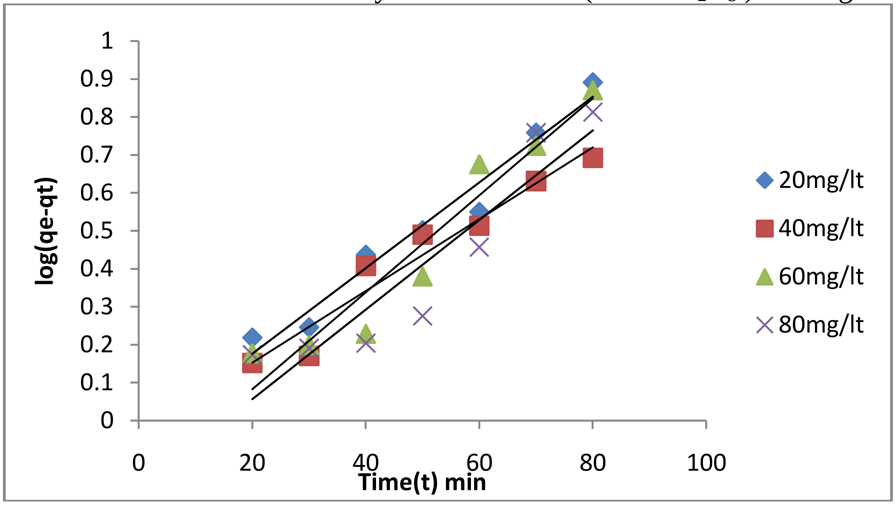

Fig-9. Pseudo 1st order kinetics of acid violet 19 dye with adsorbent(PANI-Fe_2O_3)dose 6 gm/lt.

4.2. Pseudo 2nd Order-

Adsorption kinetics were explained by 2nd order model is represented by equaion.

$$\frac{t}{qt} = \frac{1}{k2qe2} + \frac{t}{qe} \qquad (3)$$

Where K_2 is rate constant for 2nd order adsorption (g $mg^{-1}min^{-1}$),while k_2 and qe are determined from slope and intercept of plot t/qt Vs t (fig-10 and fig-11). The linear plot with corelation coefficient (r^2) 0.985 to 0.999 (as shown in table 1) shows a good agreement to the experimental qe.It shows that adsorption belongs to the 2nd order kinetics model.

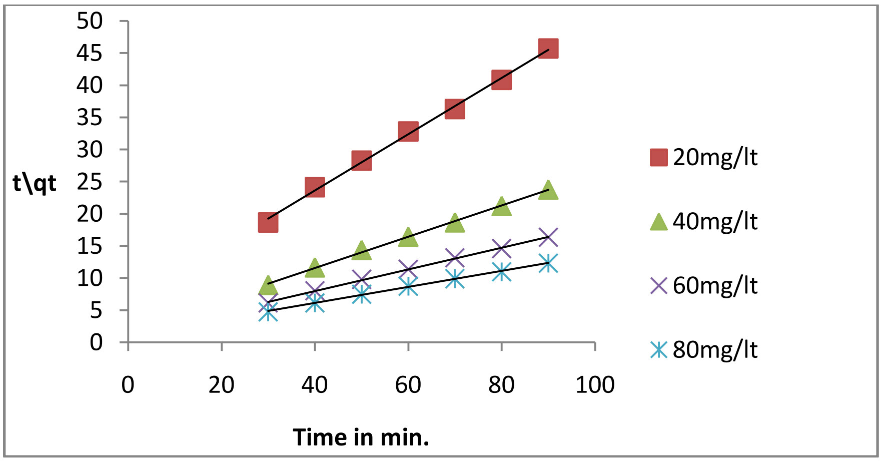

Fig-10. Pseudo 2nd order kinetics of acid violet 19 dye with adsorbent(PANI-Fe_2O_3)dose10gm/ lt.

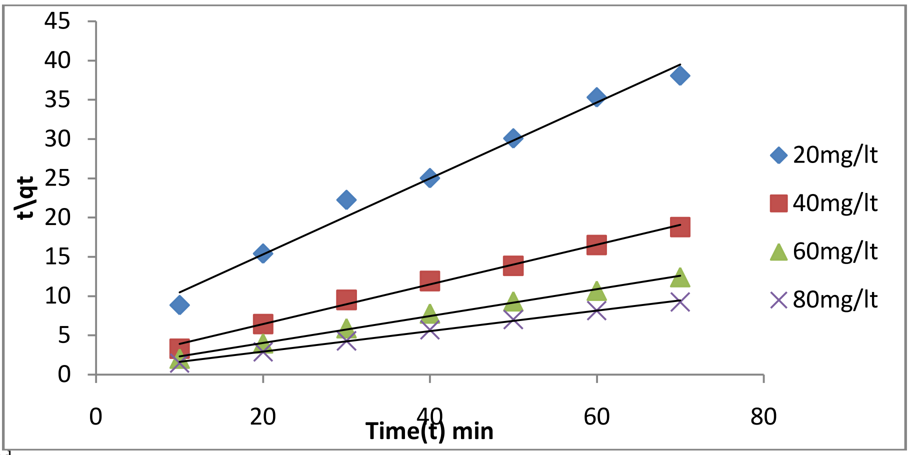

Fig-11. Pseudo 2nd order kinetics of acid violet 19 dye with adsorbent(PANI-Fe_2O_3)dose 6 gm/ lt.

Table: 1 comparisons of the pseudo first order and pseudo second order adsorption rate constants and Calculated and experiments $q_{e\ values}$ for different initial concentrations

Pseudo first order					
adsorbent dose(g/lt)	initial conc.(mg/lt)	q_e(exp)(mg/g)	q_e(cal)(mg/g)	K_1(min^{-1})	R^2
6	20	1.17	0.98	0.026	0.965
6	40	3.78	0.99	0.02	0.952
6	60	5.5	0.67	0.0294	0.927
6	80	7.3	0.66	0.027	0.866
10	20	1.96	1.37	0.023	0.96
10	40	3.92	1.07	0.002	0.933
10	60	5.78	0.67	0.025	0.948
10	80	7.7	0.45	0.031	0.863

Pseudo second order					
adsorbent dose(g/lt)	initial conc.(mg/lt)	q_e(exp)(mg/g)	q_e(cal)(mg/g)	K_1(min^{-1})	R^2
6	20	1.17	2.06	0.041	0.985
6	40	3.78	3.95	0.047	0.994
6	60	5.5	5.83	0.05	0.996
6	80	7.3	7.67	0.052	0.997
10	20	1.96	2.28	0.031	0.997
10	40	3.92	4.11	0.032	0.998
10	60	5.78	5.93	0.022	0.999
10	80	7.7	8.03	0.013	0.998

4.3. Intraparticle diffusion-

In the batch mode adsorption process, initial adsorption occurs on the surface of the absorbent. In addition, there is a possibility of the absorbate to diffuse into the interior pores of the adsorbent. Weber and Morris suggest the following kinetic model to investigate the adsorption is intra particle diffusion or not. The relationship may be given as equation (4)

$$qt = \frac{kpt\mathbf{1}}{\mathbf{2}} \qquad (\mathbf{4})$$

Adsorption is a multilayer process, involving transport of solute particle from the aqueous phase to the surface of the solid adsorbent followed by diffusion into the interior of the pores.The possibility of intraparticle diffusion is tested by plotting a graph bet^n the amount of dye adsorbed & the time $t^{\mathbf{1/2}}$ at different time intervals.Where K_P is intraparticle diffusion rate constant (mg $g^{-1}min^{0.5}$).The plot of qt Vs t ^{½} is linear indicates occurance of intraparticle diffusion as shown in fig (12 and 13).The Kp has values 0.1153 to 0.2621(mg $g^{-1}min^{0.5}$) for 20,40,60,80 mg/lt dye conc. and 10 g/lt adsorbent dose.

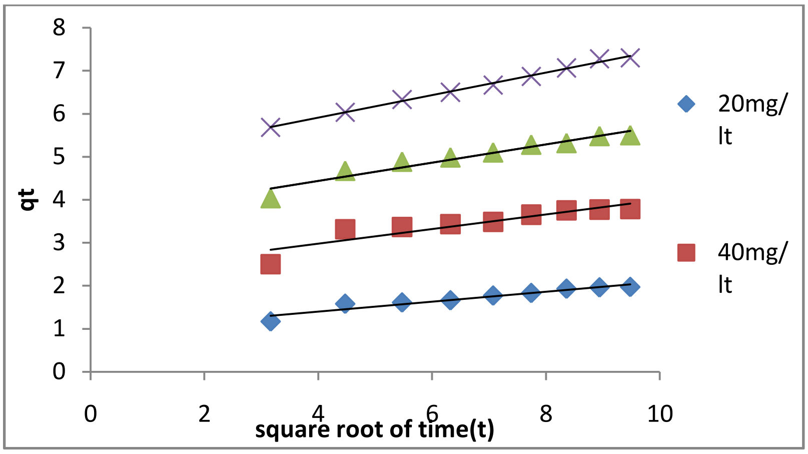

Fig-12. Intraparticle diffusion model of acid violet 19 dye with adsorbent(PANI-Fe_2O_3)dose 10 gm/ lt.

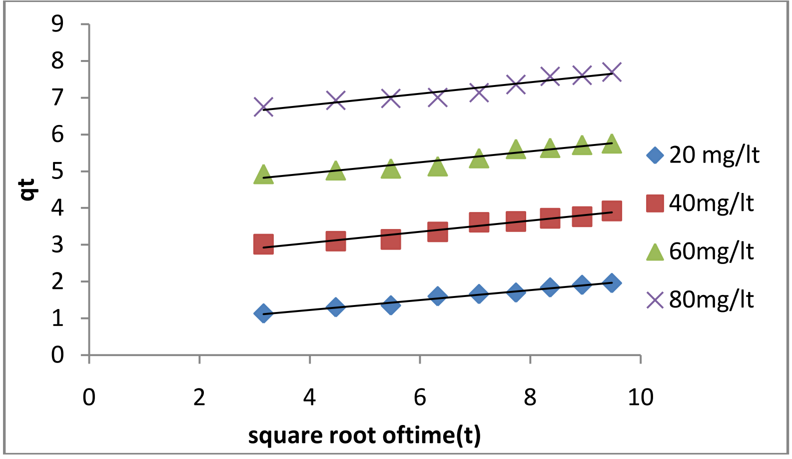

Fig-13. Intraparticle diffusion model of acid violet 19 dye with adsorbent(PANI-Fe_2O_3)dose 6 gm/ lt.

4.4 Elovich-

The Elovich equation is mainly applicable for chemisorption process. The equation is often valid for systems in which the adsorbing surface is heterogeneous [27]. The equation is given as follow

$$qt = \left(\frac{1}{\beta}\right) ln\alpha\beta + \left(\frac{1}{\beta}\right) lnt \qquad (5)$$

Where α and β are constants during any experiment. α is the initial adsorption rate (mg/g min) and β the desorption constant (g/mg) during any one experiment. The constant can be obtained from the slope and intercept of the plot of qt versus lnt (fig-14&15).The value of β decreases from 2.88 to 1.31 (g/mg) for 10 gm/lt of adsorbent dose .The β value increases from 2.54 to 2.88 (g/mg) as adsorbent dose increased from 6 to 10 g/lt for 20 mg/lt of dye conc. (Table-2).

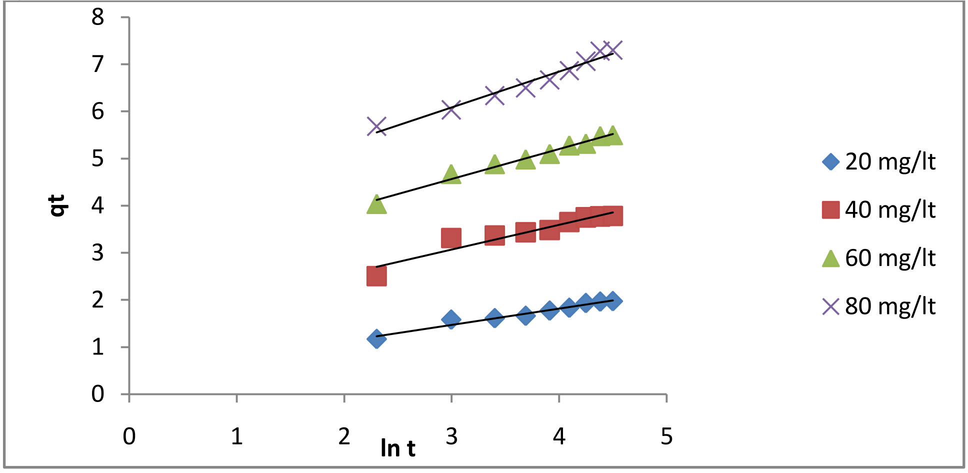

Fig-14. Elvoich adsorption model of acid violet 19 dye with adsorbent(PANI-Fe_2O_3)dose 10 gm/ lt.

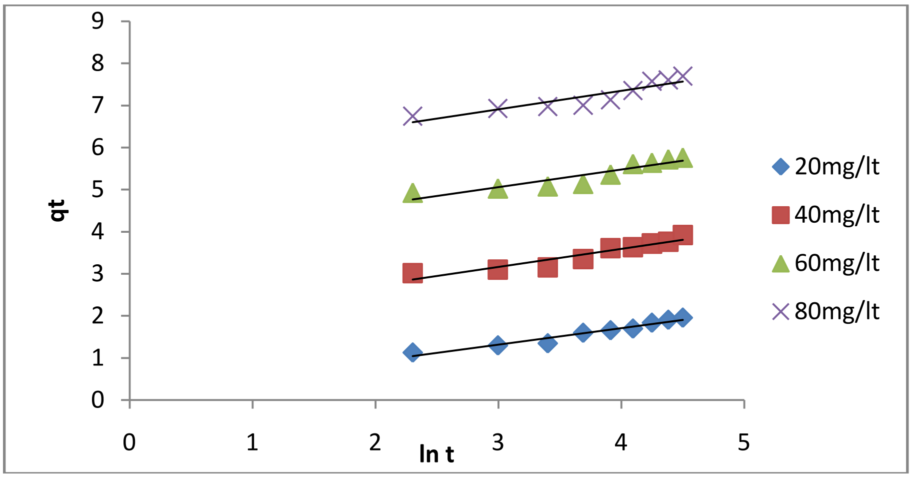

Fig-15. Elvoich adsorption model of acid violet 19 dye with adsorbent(PANI-Fe_2O_3)dose 6 gm/ lt.

Table-2. Coefficients of Intraprticle diffusion model and Elvoich model

Intraprticle diffusion model				Elvoich model			
adsorbent dose(mg/lt)	initial conc.(mg/lt)	Kp(int)	R^2	qt	α	β	R^2
6	20	0.1355	0.982	0.6947	0.269	2.54	0.951
6	40	0.1508	0.954	2.753	$3.2X10^4$	2.32	0.895
6	60	0.1487	0.93	4.626	$1.5X10^2$	2.38	0.855
6	80	0.1563	0.927	6.168	$7.9X10^{11}$	2.27	0.846
10	20	0.1153	0.922	0.863	1.51	2.88	0.961
10	40	0.1706	0.825	2.53	$1.5X10^2$	1.9	0.905
10	60	0.2118	0.939	3.559	$5.1X10^3$	1.56	0.982
10	80	0.2621	0.994	4.214	$5.2X10^4$	1.31	0.969

4.5 Freundlich isotherm-

The Freundlich isotherm is an empirical equation used to describe heterogeneous systems can be expressed in its logarithmic form as equation (6).The Freundlich adsorption isotherm equation is applied for acid fuchsin dye.

$$\log qe = \log kf + \left(\frac{1}{n}\right)\log Ce \qquad (6)$$

where q_e is the amount of dye adsorbed (mg/g) and C_e is the equilibrium concentration of dye in solution(mg l^{-1}).The Kf and n are the constants incorporating and factors affecting adsorption process.The linear plot of log qe vs log ce shows Freundlich adsorption.In adsorption Kf value increases the quantity of dye adsorbed onto the surface of PANI-Fe_2O_3 also increases (fig-16).The slope 1/n ranging between 0 and 1 is the measure of adsorption extent or surface becomes heterogeneous as its value gets closer to zero [28]. The values of 1/n is between 0.775 to 0.621 for 20 to 60 mg/lt dye conc.and adsorbent dose 10 gm/lt. It indicates chemisorption.The calculated Kf and 1/n values are presented in Table-3.

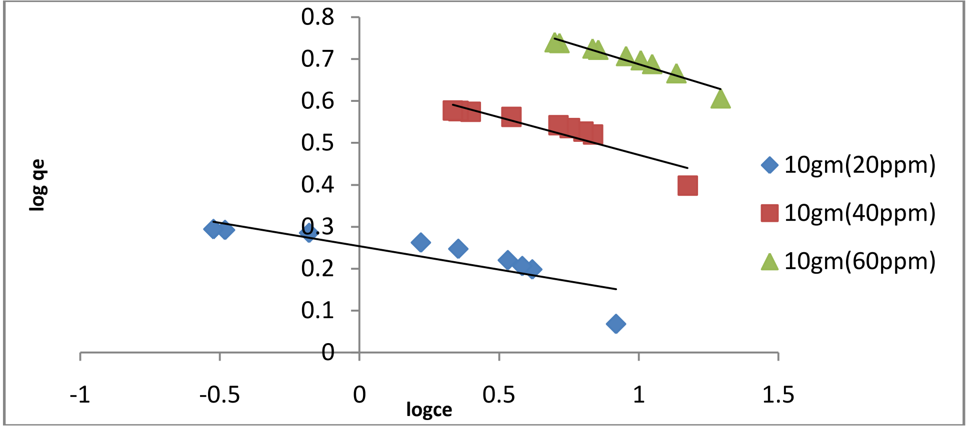

Fig-16. Freundlich adsorption isotherm for acid violet 19 dye at $_P$H 8.(Where- 1ppm=1mg/lt)

4.6 Langmuir isotherm-

Langmuir isotherm is a test on the assumption that adsorption occurs at specific homogenous sites within the adsorbent. Once an adsorbate molecule occupies a site, no further adsorption can take place. Thus, adsorption reaches to an equilibrium value. The saturated monolayer curve can be express in the equation given below. It has been successful for the explanation of monolayer adsorption. The linear form of Langmuir equation is given as:

$$\frac{Ce}{qe} = \frac{1}{Q0b} + \frac{ce}{Qo} \qquad (7)$$

Where C_e is the equilibrium concentration (mg/L),qe amount of dye adsorbed at eqquilbrium (mg/g) and Qo(mg/g) is the monolayer coverage capacity, b is Langmuir isotherm constants(l/mg). The values of Q_o and b are determined from the slope and intercepts of the linear plots of ce/qe Vs ce.It is shown in the (fig- 18) .calculated Q_o and b values are presented in Table-3. The Langmuir adsorption suggest the monolayer coverage of dye on PANI-Fe_2O_3 nano-composite.The essential characteristics of the Langmuir isotherm can be expressed by dimentionless constant called equilibrium parameter.

$$RL = \frac{1}{1+bCi} \qquad (8)$$

where b is the Langmuir constant, Ci is the initial dye concentration (mg/lt).According to the rule of RL.RL≥1 Unfavorable, RL=1 linear, 1≥RL≥0 Favorable, RL=0 Irreversible.When the rule 1≥RL≥0 is obeyed, Langmuir isotherm becomes favorable. The corelation coefficient of r^2 values for Langmuir and Freundlich isotherm are shown in Table-3. Both the isotherms are found to fit well to experimental data and agree with literature [29-31].

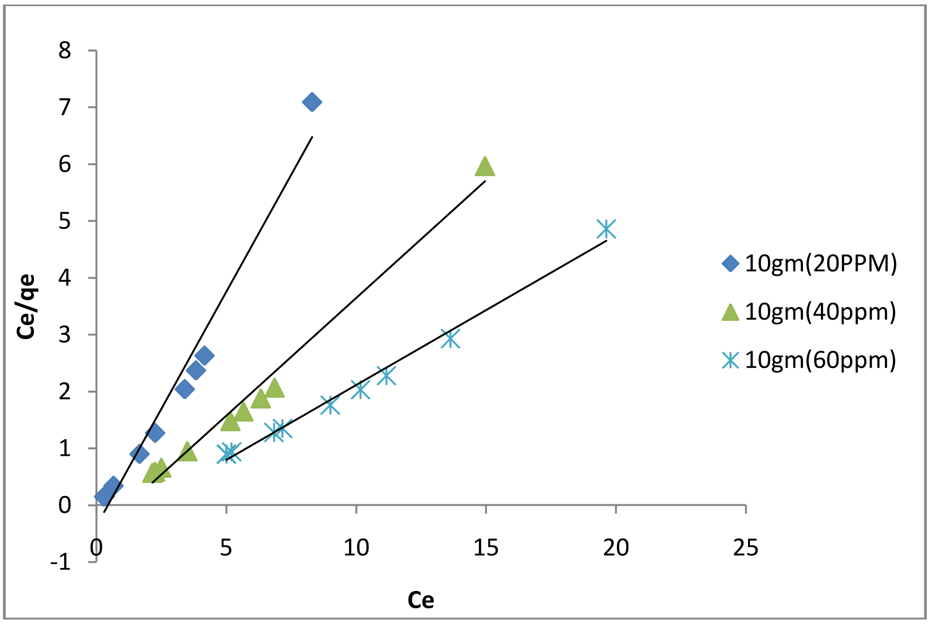

Fig-17. Langmuir adsorption isotherm for acid violet 19 dye at $_P$H 8. .(Where- 1ppm=1mg/lt

Table-3. Freundlich and Langmuir coefficients for adsorption of acid violet 19 dye on PANI-Fe_2O_3 for different dye concentration at pH 8.

Freundlich coefficients						Langmuir coefficients			
adsorbent dose (mg/lt)	initial conc.(mg/lt)	Kf(l/g)	n	1/n	R^2	Q_0(mg/g)	b	RL	R^2
6	20	35.48	0.95	1.052	0.799	0.977	1.89	0.025	0.977
6	40	17.78	1.35	0.74	0.935	0.995	2.37	0.01	0.995
6	60	14.45	1.21	0.826	0.951	0.798	0.5	0.032	0.798
10	20	1.79	1.29	0.775	0.7443	0.97	2.27	0.0211	0.97
10	40	4.47	1.51	0.662	0.853	0.984	0.835	0.029	0.984
10	60	7.76	1.61	0.621	0.931	0.99	0.507	0.046	0.99

Conclusions

1. PANI-Fe_2O_3 nano-composite is successfully synthesised in situ through self polymerisation of monomer aniline.
2. Adsorptive removal of acid violet 19 dye by using adsorbent dose (PANI-Fe_2O_3) is successfully applied. The adsorption rate increased significantly by increasing amount of adsorption dose, while with an increasing dye concentration adsorption rate decreases. Basic $_{P}$H condition is found, which significantly affect the dye adsorption efficiency of acid violet 19 dye is 98.5% and after elution the concentration of dye is 20 mg/lt.
3. The present study shows that conducting PANI-Fe_2O_3 can be used adsorbent for the removal of acid violet 19 dye from aqueous solution.
4. The amount of adsorbed dye is found from 1.7 to 7.7(mg/g) increased with an increase contact time and increase in initial dye concentration with an increasing adsorbent dose.
5. The rate of adsorption is found to confirm the pseudo second order kinetics with good correlation with R^2 values.
6. It is found that Elvoich model has good correlation with R^2 values, which indicates chemisorptions.
7. Adsorption isotherms are described by Langmuir isotherm and Freundlich isotherm models. Freundlich isotherm model is found to fit with experimental data due to higher 1/n and K_F values.

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