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Adsorption and Kinetic study of priority organic pollutant phenol from aqueous waste using Activated carbon

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Abstract

Many organic compounds present in industrial and domestic wastewater are carcinogenic in nature. Removal of these organic compounds from waste waters has become a great challenge to waste water treatment technologies as many of them are non-biodegradable in nature. Adsorption on activated carbon has emerged as an efficient and economically viable technology for the removal of a broad spectrum of toxic organic compounds from domestic and industrial waste water. The adsorption of hazardous organic compounds on activated carbon has been the subject of research for the past three decades. In the present study, kinetic study for adsorption of some priority organic pollutants like phenol on activated carbon, was studied at laboratory scale. Series of experiments were carried out to determine kinetics for adsorbate, when present in aqueous solution as a single component. The commercially available bituminous coal based activated carbon Filtrasorb-400 was used as an adsorbent. A simplified interpretation of the kinetic data based on Langmuir theory has been used. The kinetics performed gives the adsorption equilibrium time. The adsorption and desorption rate constants were evaluated from the graph.

Keywords: Activated carbon, Kinetics, Adsorption, SEM, Phenol.

Introduction:

The presence of phenols in natural water have resulted in different environmental problems resulting in development of different methods for the removal of Phenols [1].The main sources of phenols in environment are production of drugs and several pesticides like pentachlorophenol, dinoseb or diaryl-ether pesticides[2]. Mostly phenols and their derivatives are released into the environment through municipal/industrial waste, and landfill leachate [3]. The presence of phenolic compounds have been documented in different mediums such as sewage sludge, influent and effluent of wastewater, river water and soil [4-7]. Phenols are also included in The List of Priority Pollutants by the US Environmental Protection Agency (EPA) [8]. The removal of such dangerous pollutants to permissible limit is mandatory as per environment protection Laws. They are also highly toxic which is very important due to ecological aspects [9]. Chronic toxicity of phenols in humans results in: headache, vomiting, difficulty in swallowing, liver injury, fainting and etc. [10]. Therefore, due to the environmental and ecological safety it is advisable to clean municipal and industrial wastewater.
Among the methods used to phenols removal, adsorption is one of the simplest and widely applied method. Activated carbon in modern technology of water treatment for organic pollutants is an effective adsorbent primarily due to its extensive porosity and very large surface area. Fundamentally important characteristics of good adsorbents [11, 12] are their high porosity and consequent larger surface area with more specific

adsorption sites [13]. Examination of wastewater treatment containing phenolic compounds, have shown that adsorption on activated carbon is considered as a most potential treatment technique [9,10,14]. Commercially available activated carbon was used in this study and adsorption kinetics in batch system were carried out. The carbon was characterized to analyze its structural and adsorption properties.

2. Materials and Method:

Materials: Phenol of analytical reagent grade of reputed company such as Merck, India, and bituminous coal based activated carbon F400 were procured from local market.

Spectrophotometric Method of Estimation of Adsorbate phenol

The adsorbate concentration in their aqueous solutions, were determined by the UV/VIS absorbance spectroscopy. Adsorbate concentration of the solution was measured by UV/VIS spectroscopy by measuring the optical density of the components at their respective wavelengths of maximum absorbance. The complete analytical work of UV/VIS. absorption measurements were carried out on a Perkin Elmer Lambda 35 UV/VIS spectrophotometer. The absorbance measurements were carried using matched 1cm path length glass and quartz cuvettes. The adsorbate used in the present work had very strong absorption bands at 270 nm. The absorption maxima and molar extinction coefficient (ε) values are reported in Table 1.1.

Adsorption Kinetics

For adsorption kinetic studies, the experimental unit was a cylindrical batch reactor having a capacity of 7 litres. It was made of borosil glass and was fitted with eight baffles. The adsorbent-adsorbate system was stirred by a two bladed impeller having length of 7 cm and breadth 1.5 cm . The impeller used to stir the experimental solutions was fabricated out of a 6mm glass rod having a simple teflon or nylon paddle fitted to its lower end in such a way that it used to move freely about the axis of the rod but did not slip out. It was also prevented from sliding upwards during stirring by a mechanical stop which was attached to the glass rod. Experimental solution for kinetic runs was four liters in volume and was prepared by preparing appropriate amount of stock solution with boiled and cooled distilled water. The contents were constantly stirred at 800 ± 50 RPM and allowed to attain the temperature of the bath, which usually took around 25 to 30 minutes. 1.000±0.0001 g/l of a given activated carbon sample of phenol was then introduced into the solution at a given instant of time. At every desired interval of time, 8 ml of experimental solution was withdrawn with the help of a syringe, centrifuged and the concentration of the adsorbate in the aqueous phase was estimated by UV/VIS analysis.

Table 1.1Ultraviolet absorption spectroscopy data of Adsorbates

Sr. No.	Adsorbate	λ max(nm)	ε ($cm^{-1}ppm^{-1}$)	R^2
1	PH	270	0.0149	0.9983

Results and discussion:

Physico-chemical (Elemental) analysis: The data obtained for physicochemical properties of the activated carbon are presented in Table 1.2 , The values describing Brunauer Emmett Teller surface area (BET), Iodine and methylene blue (MB) numbers of the ACs shown in Tables illustrates that the activated carbon have better application in phenol removal. Fig 1 represents SEM micrographs and Fig 2 represents results for XRD analysis for the studied AC.

N2-BET Surface area measurement: Specific surface area was determined by the N_2-BET isotherm technique using a Micromeritics ASAP 2010 surface area analyzer. The samples were initially outgassed at 393 K for 24 h before adsorption isotherms were generated.In controlled increments, an adsorptive (usually nitrogen) is added to the solid. The amount of gas adsorbed is estimated after the pressure has been allowed to equilibrate following each dose of the adsorptive. The volume of gas adsorbed at each pressure defines an adsorption isotherm at constant temperature, from which the amount of gas needed to cover the solid's exterior and its pores in a monolayer may be calculated. The surface area can be computed if the area that each adsorbed gas molecule covers is known.

Table 1: Physico-chemical analysis of activated carbon:

Activated Carbon	M%	A%	V.M%	F.C%	C%	H%	N%
F-400	5.4	5.5	2.7	86.4	95.32	0.27	-

Table 2: Results for Iodine Number and B.E.T surface area.

Activated Carbon	Iodine Number	B.E.T surface area m^2/g
F-400	1050	1130

SEM morphology analysis and XRD pattern of F400:

The physical surface morphology was examined using a JEOL Scanning Electron Microscope (JSM-6380 Model No.). A thin layer was mounted on the Al specimen holder by a double-sided tape. It was coated with Au/Pd, with a thickness of about 30 nm. The SEM of ACs was recorded at 500 x and 3000x magnifications. It could be observed from Fig.1 that the surface is full of various shape and sizes of pores. It indicates that the precursor material is adequate for the purpose. XRD pattern of F400 suggested amorphous nature of carbon with broad peaks of amorphous phases shown in fig 2.

Fig.1

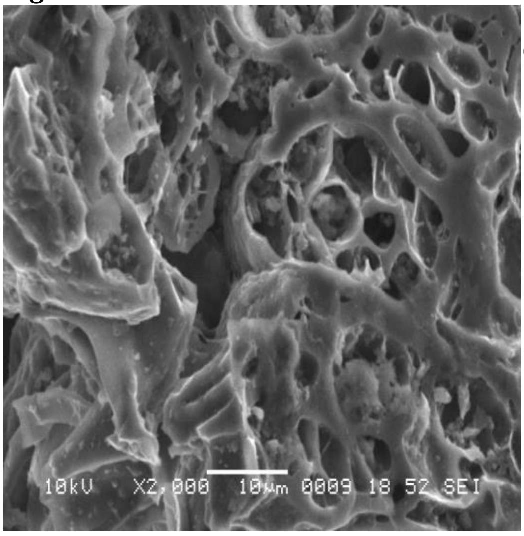
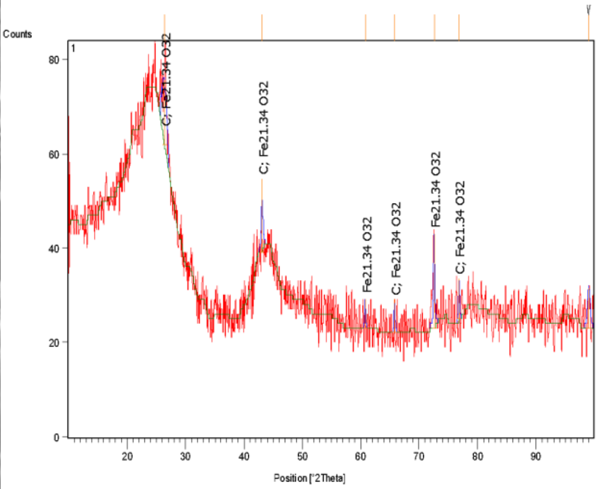


Fig.2



Adsorption Kinetics:

The Kinetics was performed to know the adsorption equilibrium time. A simplified interpretation of the kinetic data based on Langmuir theory was used and the rate was expressed as a function of a directly measurable system variable, the fluid phase adsorbate concentration. Following rate equation based on Langmuir theory was used to analyze the kinetic data;

$\ln [(C_t-C_e)/(C_t+a)] = -k\, C_e t + \ln [(C_0-C_e)/(C_0+a)]$

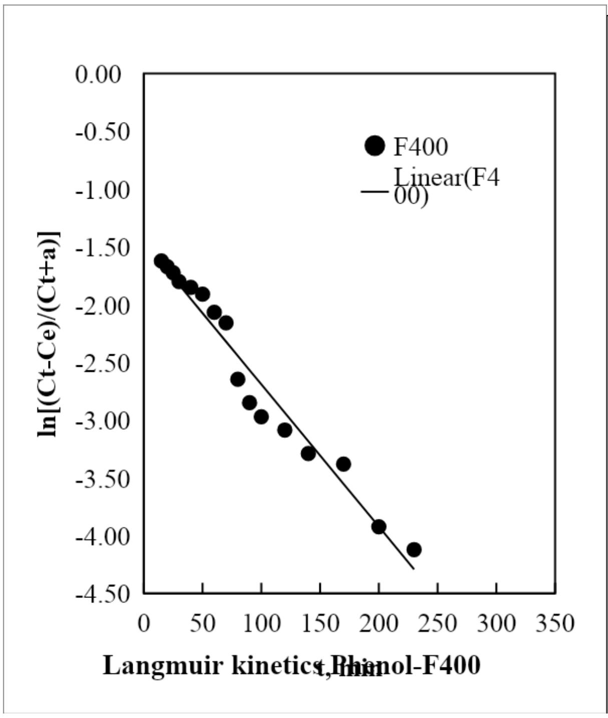
Where, $a= (C_0/k\, C_e)$

Table 1.2: Adsorption kinetic studies on prepared Activated Carbon

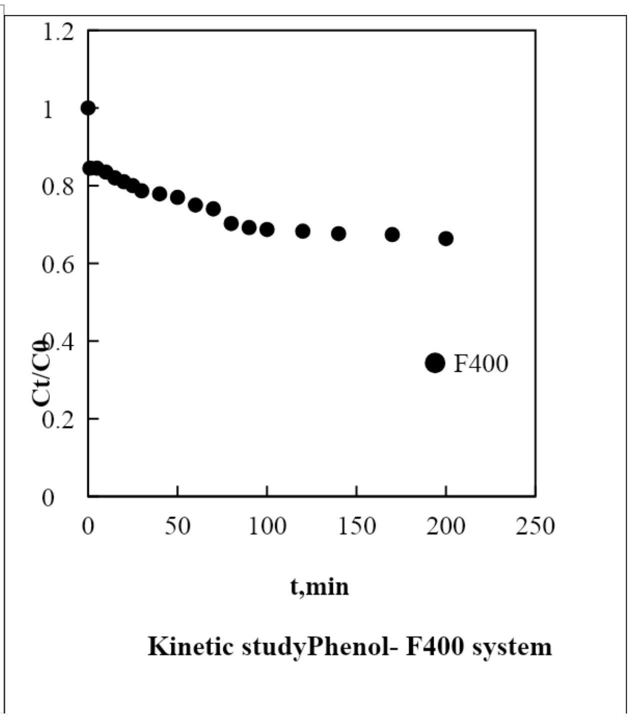
Adsorbent	Langmuir adsorption constants		Langmuir Kinetic Constants	
Activated carbon	**Q^0**	**b**	**K_a**	**K_d**
F400	142.86	2915.45	1.42E-04	3.57E-08

Fig.3

Fig.4



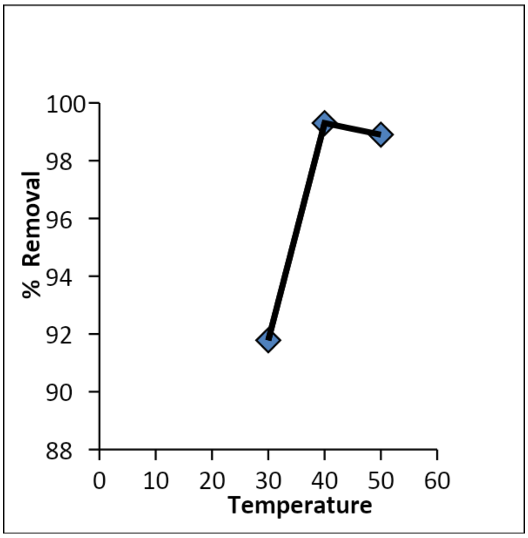
Langmuir kinetics Phenol-F400



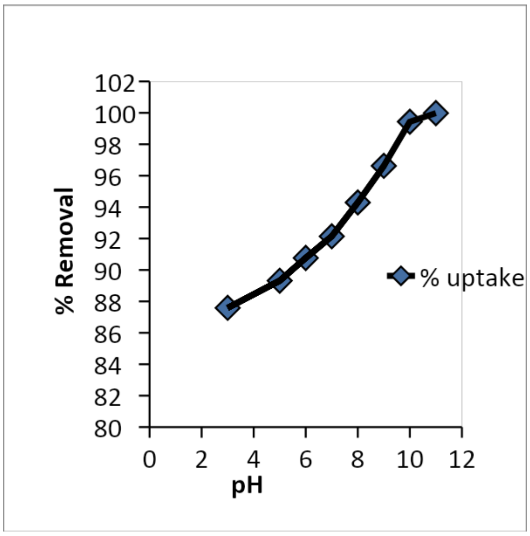
Kinetic studyPhenol- F400 system

Effect of Various Parameters:

Effect of Temperature



Effect of pH on adsorption



Effect of adsorbent dose on adsorption

Conclusions:

A scanning electron microscopic study shows that the external surface of activated carbon is full of cavities showing presence of micro as well as meso pores. The adsorption rate is very much higher than the desorption rate. F400 is highly porous and amorphous in nature facilitating phenol adsorption. The pH of an aqueous medium is an important factor that affects the uptake of the adsorbate.F400 removes phenol at a wide range of pH which is limitation in most of the adsorbents. Phenol removal increases with increase in temp up to certain level then remains almost constant.

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