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Study of some Effecting Factors on the Removal of Phenol from Aqueous Solutions by Adsorption onto Activated Carbon

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Abstract: The current study aims to remove organic pollutants (phenol) from industrial effluent using batch adsorption on activated carbon. Batch mode adsorption experiments were performed by varying of some different parameters such as particles size, contact time, weight of adsorbent and pH of the solution. The obtained results indicate that the adsorption of phenol increases with increasing the pH value of the solution and also mixing time. It seems that the mixing time of 120 minutes is fixed as the optimum contact time for adsorption of phenol onto activated carbon. The results also show that, the adsorption data fit well with freundlich model of adsorption isotherm.

Keywords: *Activated carbon, Phenol, Adsorption, Adsorption Isotherm.*

Introduction

Industrial effluent is one of the major sources of environmental pollutant causing damage to aquatic and human life due to mutagenic or carcinogenic effects (Crini, 2006). Phenol is an organic contaminant and a durable toxic, which causes cancer which can be found abundantly in wastewater of various industries such as coal transformation in high temperature, crude oil refining, production of resins and plastics, synthetic colors and herbicides (Khanahmadzadeh *et al*., 2012) petroleum refineries, petrochemical and fertilizer, pharmaceutical, chemical and dye industries (Girish & Murty, 2012).

Phenol is the priority pollutant since it is toxic and harmful to organisms even at low concentrations. The maximum permitted concentration level of phenol being 0.5-1 mg/l for industrial wastewater and 1µg/liter for drinking water. So it is highly essential to save the water resources and aquatic life by removing these compounds from wastewater before disposal (Rao, 2013). Several methods, such as bio-degradation, adsorption, chemical oxidation, solvent extraction and reverse osmosis are being used for removing phenols from wastewater (Bohli *et al*., 2013).

Adsorption, as a simple and relatively economical method, is a widely used technique in the removal of pollutants (Dakhil, 2013). Although the adsorbents used may vary due to the change in adsorption conditions depending on the type of pollutants, the properties affecting the efficiency of an adsorbent are; a large surface area, the homogeneous pore size, well defined structural properties, selective adsorption ability, easy regeneration, and multiple use (Dakhil, 2013, Banat *et al*., 2000).

Activated carbons, the most important commercial adsorbents, are materials with large specific surface areas, high porosity, adequate pore size distributions and high mechanical strength (Bohli *et al*., 2013). Activated carbon either in granules or powder form has good capacity for the adsorption of organic molecules. They have ability to attract to their surface soluble materials such as phenol from solution (Dabhade *et al*., 2009).

In this study, the ability of activated carbon as adsorbents was reported for the removal of phenol effluents from the industrial activities.

Materials and Methods

Preparation of Activated Carbon

The type of activated carbon was used in research is Granular activated carbon (GAC). Grinding (GAC) by FRITSCH planetary mono mill and then sieved sample to different size fractions (45, 75, and 212 µm), for laboratory tests.

Characterization of Activated Carbon

- Characterization by SEM type Tescan Vega 3 (Czech).
- Characterization by FT-IR type Shimadzu by using KBr to analysis the sample.

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- Surface Area and Porosity.

The Brunauer-Emmett-Teller (BET) surface area of activated carbon powders were determined by nitrogen adsorption. In this work, adsorption of nitrogen at 77.3K was used to determine parameters like surface area and pore volume.

Preparation of Solutions

A standard stock solution of phenol (100 ppm) prepared by dissolving (0.1gm) of phenol crystal (ROMIL Ltd. /England) in (1liter) from deionized distilled water (DDW). Several concentrations (0.07, 0.1, 1, 5, 10, 15, and 20 ppm) were prepared from standard stock solution.

Adsorption Experiments

In the batch adsorption experiment, a predetermined amount of adsorbent (Activated Carbon) is mixed with known amount of phenol solution (Adsorbate), and stirred for constant contact time by oscillating shaker and subsequently is separated by filtration. Batch adsorption studies were focused on the effect of various parameters namely, pH, adsorbent dosage, initial concentration, contact time and temperature (Muthamilselvi *et al.*, 2012). Batch adsorption experiments were conducted to evaluate the equilibrium characteristics for the adsorption of phenol compound on adsorbent (Activated Carbon), then their adsorption isotherm could be indicated.

The experiments were carried out as follows:

1. Accurately weighed amounts of (Activated Carbon Powder (0.15 gm) were added to three dark stoppard bottles (100 ml) in capacity, filled with the same volume of known concentration phenol, at room temperature (25^{o} c).
2. A shaker with a variable speed control was constructed to facilitate the mixing of the powdered in the test solution. The speed of the shaker was selected to be 150 rpm.
3. Bottles were closed with stoppers and put them in a shaker oscillating to reach equilibrium conditions.
4. Mixture was filtered completely through 15 cm Whatman filter paper No.1001. The stander and residual phenol concentrations were analyzed using HPLC (High Performance Liquid Chromatography type (Shimadzu LC-2010AHT; Japan).

Adsorption isotherms were obtained by plotting the amount of organic adsorbed by mg/g versus the corresponding equilibrium concentration. The amount of phenol adsorbed by the adsorbent was calculated from the equation (Achmad *et al.*, 2012).

$Qe = V (Co– Ce) / m$

Where V: is the volume of solution (ml), m is the mass of the adsorbent (gm), C_O is the initial concentration (mg/L) and C_e is the concentration at equilibrium (mg/L).

Analytical Method

The phenol concentrations were determined by high-performance liquid chromatography (HPLC) type (Shimadzu LC-2010A HT, Japan). The column packing ODS-C_{18} (octadecylsaline) 5µm and made out of stainless. The dimension of column was (25cm x 4.6 mm). Mobile phase was prepared from acetonitrile and deionized water (30:70). The column was washed with acetonitrile and deionized water before every analysis.

Results and Discussion

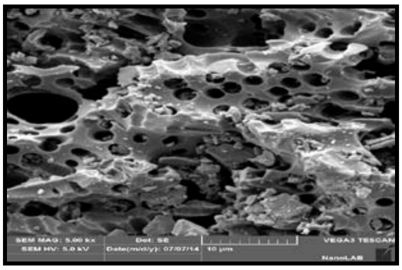
Characterization of the surface morphology of activated carbon was studied using different tools:

The SEM (Fig.1**)** indicates the external surface of the activated carbon is well-developed porous structure. The external surface shows a rough area having different pore diameters distributed over the surface of activated carbon. The surface area and porosity as shown in Table 1 which indicates the BET surface area, pore volume and pore diameter values of activated carbon.

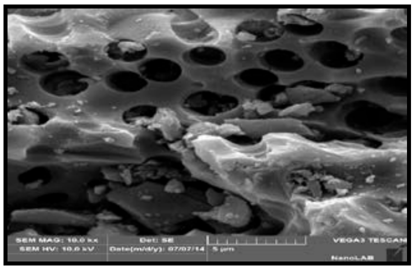
Table 1. BET Surface Area, Pore Volume and Pore Diameter Values of the Samples.

SI. No	Sample	BET Surface area (m^2/g)	Pore Volume (cm^3/g)	Pore Diameter (nm)
1	Activated carbon	734.534	0.025	3.116

In order to indicate the active groups or site of the adsorbent material, FT-IR has been studies.The results of FT-IR spectra (Fig.2) showes the existence of C-H groups at (3000-2800) cm^{-1}, C=C at 1571.01 cm^{-1}, C-O at 1139.28 cm^{-1} ,C-C at 670.39 and 654.49 cm^{-1}. This might have an influence on the adsorption process.



a) SEM Image of Surface AC in 5.00 KX Magnifications



b) SEM Image of Surface AC in 10.0KX Magnifications

Figure 1. SEM Image of Surface AC

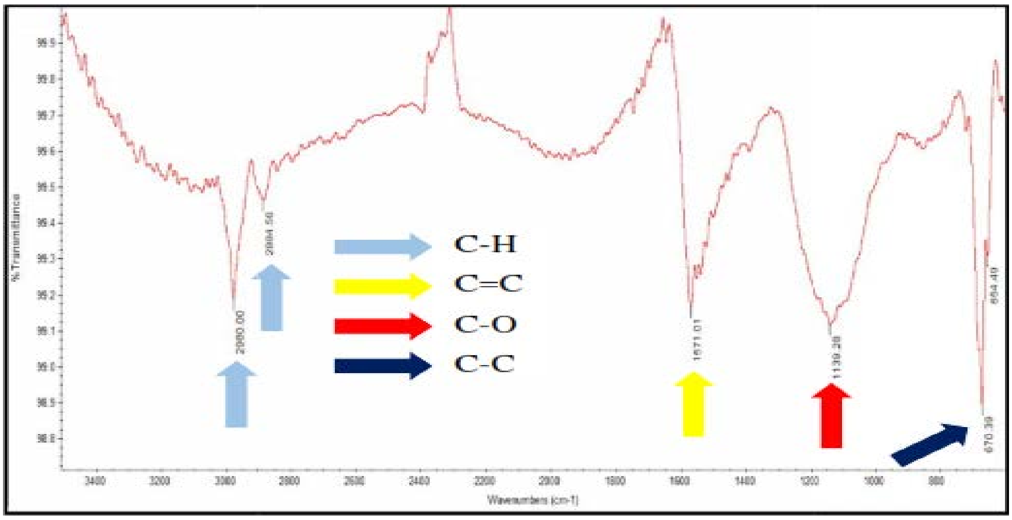


Figure 2. FTIR Spectrum of Activated Carbon

The Factors Effecting of the Phenol Adsorption

pH

The effect of pH on the adsorption of phenol in different solutions pH= (3, 5, 9, 10 and 12) HCl (1N) and NaOH (1N) has been studied, by using a constant concentration (Co=20 ppm). Figure 3 shows the removal percentage of phenol increased with increasing pH values of the solution. The pH of solution is one of the most important parameter effecting phenol adsorption processes and has an effect on the active sites adsorption, the activated carbon is heterogeneous surface contains positive and negative sites. At low pH, the number of cation is increased then most of them are attracted to the negative sites result to electrostatic forces. In other words positive sites become repulsion points with cation and then decreased the adsorption in acidic solution. Where at high pH, increasing the number of negative ions then most of them are attracted to the positive sites. It means negative site become repulsion points with negative ions and this leads to increase adsorption in the alkiane solution. However it is found that the best adsorption has been recorder for pH value 12 which represents the higher used pH value for this study.

Contact Time

The effect of the contact time between (phenol) and (AC) have been studied on the adsorption process at different contact times (30, 60, 90, 120,150, and 180 minutes), and at constant concentration (C_o=20 ppm), and at room temperature (25° c). (Fig.4) indicate a rapid adsorption at (30, 60) minutes, and followed by a gradual increase in adsorption with increasing contact time to 120 minute. At 120 minutes contact time, seems that the adsorption is more or less constant. Therefore, the mixing time 120 minutes is fixed as the optimum contact time, where a saturation adsorption has been shown.

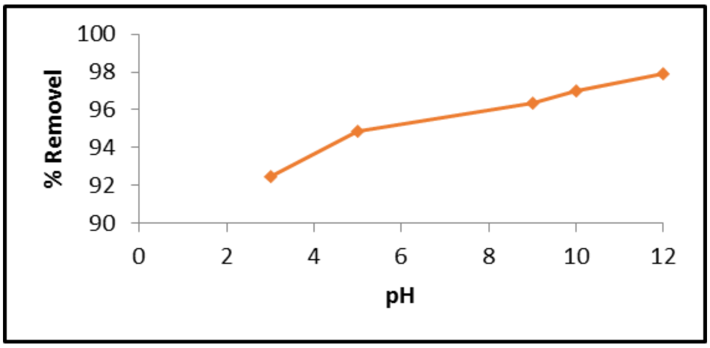


Figure 3. Effect of the Different (pH) on the Adsorption Process

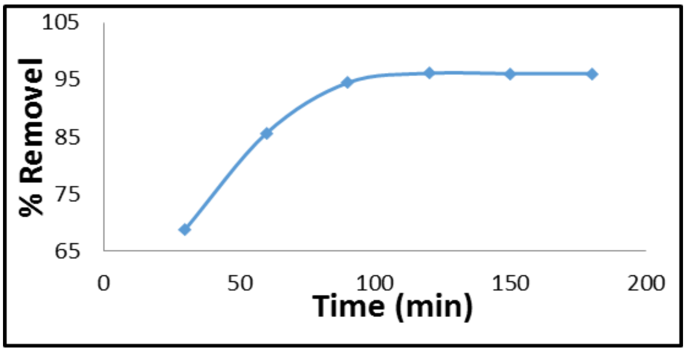


Figure 4. Effect Contact Time on the Adsorption Process

Particle Size

Figure 5 showed that the removal percentage of phenol increased with decreasing the particles size of the adsorbent. It seems that the fine particles with 45 µm were more effective for phenol removal than the coarser partials, because the decrease of particle size of the adsorbent causes an increase of the surface area which leads to create more active sites on the surface of the adsorbent and this increases the removal percentage (Dabhade *et al.,* 2009).

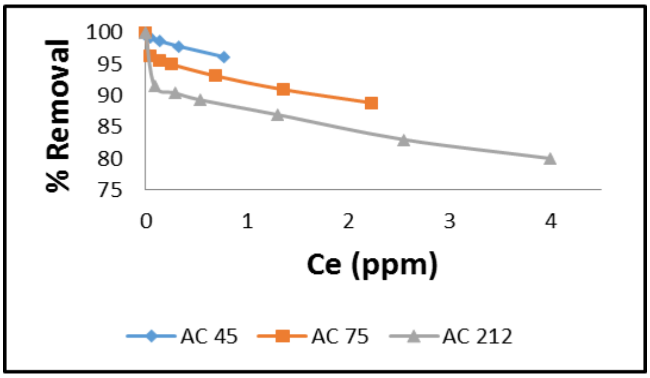


Figure 5. Effect of Particle Size for the Adsorption of Phenol on the Surface Activated Carbon

Adsorbent Weight

Figure 6 shows shows the effect of adsorbent weight on the phenol removal, it seems that the removal percentage of phenol increased with increasing in adsorbent weight. This can be attributed to increase adsorbent surface area and availability of more adsorption active sites resulting from the increased adsorbent weight (Uddin *et al.*,2007) so the adsorption process is less when decrease the weight of adsorbent material.

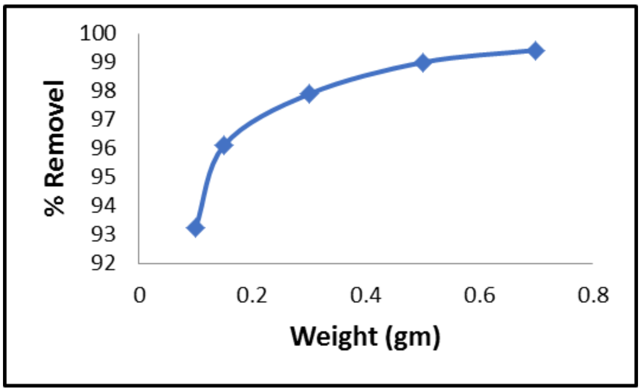


Figure 6. Effect of Adsorbent Weight on the Phenol Adsorption

Adsorption Isotherm

The general shape of the adsorption isotherms, for phenol on activated carbon which are fitted with freundlich model from plotting the amount of the adsorbate Qe versus concentration equilibrium (C_e), as shown in (Fig. 7). The amount of phenol adsorbed by the adsorbent was calculated from the equation.

$$Q_e = V\,(C_o - C_e)\,/\,m$$

Where Qe = quantity of adsorbent (mg), V = volume of solution (ml), Ce= initial concentration (mg/l), Co = concentration at equilibrium (mg/l) and m is the mass of the adsorbent (gm).

Figure8 shows a plot of log Q_e against log Ce in order to obtain freundlich constant. The plot gives a straight line. The slope of isotherms model as constants were found to be = 0.5851 for the adsorption of phenol onto activated carbon.

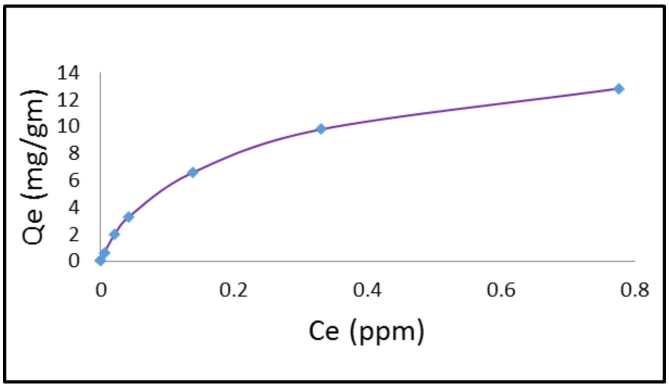


Figure 7. The Adsorption Isotherm of Phenol onto the Surface Activated Carbon

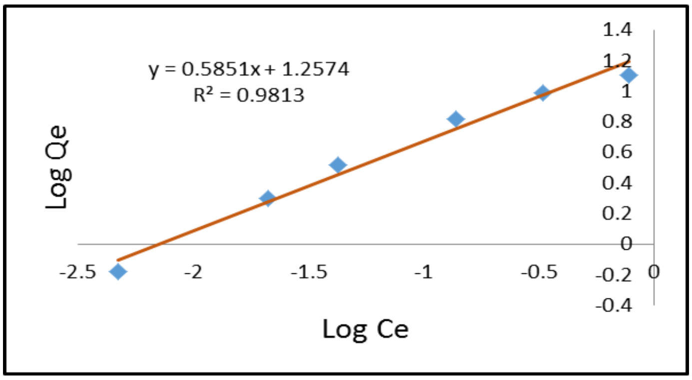


Figure 8. The Constant of the Freundlich Equation onto Surface Activated Carbon.

Conclusions

In this study, the adsorption of phenol from aqueous solution using activated carbon (AC) was investigated. Results indicate that removal percentage for phenol on activated carbon was considerably affected by different factors such as: pH, particle size, contact time and weight of adsorbent. The phenol adsorption increased with increasing pH value, weight of adsorbent and decrease with the increase of particle size of activated carbon .Mixing time of 120 minutes is fixed as the optimum contact time for adsorption of phenol on activated carbon. The experimental data showed that the applicability of the freundlich model onto adsorption process by using activated carbon. It can be concluded that the activated carbon has the ability to remove organic pollutant (phenol) with different concentrations.

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