

## Adsorption of Phenol from Wastewater Using Different Adsorbent Materials

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### Abstract

Pollution of water by phenolic compounds is considered extremely hazardous to the environment due to its negative impacts on the surroundings and health. To help rectify these issues, adsorption method has been gained much interest for wastewater treatment. The core objective of this research is to investigate the removal of phenol from aqueous solutions using various low-cost and eco-friendly materials, including activated carbon (AC), local coal (LC), silica gel (SG), local sand (LS), bentonite (BNTN), and carpentry (C). The main parameters affecting on sorption of phenol were investigated including initial concentration, contact time, and PH. The adsorption experiments were conducted for initial concentrations of phenol in the range of 5 - 100 ppm. The results showed that the maximum values of removal percent were 95%, 55%, 46%, 19.5%, and 45% for AC, LC, SG, LS, and BNTN, respectively. The experimental data showed that the removal of phenol is fast kinetics and reach of equilibrium within 5 mins. The results indicated that AC was the more effective material for adsorption of phenol than the other studied sorbents. The maximum removal percent of phenol was achieved is 95%. The Langmuir and Freundlich isotherm models were applied to fit the adsorption experimental data.

*Keywords:* Wastewater treatment; adsorption; phenol removal; Langmuir and Freundlich isotherms.

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### 1. Introduction

Wastewater pollution is considered to be one of the most issues in human life. Among of water pollutants, phenol and their derivatives that can permit to ground water from different aqueous industrial wastes such as distillation units, petrochemical industries, and chemical laboratories [1, 2]. The most phenolic compounds present in wastewater accumulated from different industries such as petrochemical, pharmaceutical, plastic, paint, solvent, coal conversion, and paper [1, 7]. Furthermore, petroleum and petrochemical industries were considered as most source of phenol in environment system that consists of this

phenol waste in huge amount [3]. The environmental organizations consider phenol and their derivatives as hazardous and toxic compound because corrosive, combustible and the high toxicity on human life either by inhalant, ingestion or just by skin contact [4]. By reaching 71.5°C the phenol is becoming auto ignition. Phenol is a volatile, combustible solid that when heated gives off flammable vapors and carbon dioxide [4, 5]. Moreover, phenol is sensitive to oxidizing agents [5]. According to United State Environmental Protection Agency (EPA) phenolic compounds have been categorized as containment in wastewater [6]. Recently various methods have

been investigated for the International Journal Of Engineering And Science Vol.3 (May 2013), PP 25-31. removal of phenolic compounds from waste water such as adsorption, photo decomposition, volatilization and biological method methods [1, 7]. The results in literature indicated that the adsorption is the efficient method for removal wastewater treatment due to low cost, high efficiency, operating at wide range of temperatures, and low energy consumption [8]. The objective of this research is to investigate the performance of different eco-friendly materials for adsorption of phenol including activated carbon, local coal, silica gel, local sand, carpentry and bentonite to remove phenol from wastewater. In addition, effects of adsorption parameters on the phenol removal have been studied. Furthermore, Langmuir and Freundlich isotherms have been fitted with the obtained experimental data.

## 2. Materials and Methods

### 2.1. Adsorbent materials

Phenol (98.90% BDH) was purchased from chemicals ltd Pool, England. Various adsorbents were used for phenol removal, including activated carbon (AC), local coal (LC), silica gel (SG), local sand (LS), bentonite (BNTN), and carpentry (Ca). Table (2.1) represents the properties and sources of the sorbents.

### 2.2. Adsorbate

A stock solution of phenol was prepared by dissolving 1g of phenol in 1000 ml (1 liter) distilled water. The stock solution was then diluted to appropriate concentrations that used for each experiment. Calibration curve with concentration ranging from 0-100 ppm was obtained. UV.VIS Spectrophotometer (JENWAY, MODEL- UV-6305) was used for investigation of phenol concentration at wavelength of 269 nm.

### 2.3. Adsorption Procedures

Adsorption experiments were performed at room temperature. The experiments were carried out by adding an amount of adsorbent (0.5g) with 20ml to phenol solution 100ppm in 50ml stopper Conical flasks, these flasks were placed on a shaker (Johanna Ottogmbh, ks50a, 6171BR00525 Germany).

The shaker speed was fixed at 200 rpm to maintain the equilibrium condition. The pH of phenol solution was sat at about 7. The effect of the contact time of phenol removal was carried out at different periods (5, 10, 20, 30, 60, 120, 240 min). Samples were filtered from sorbents by normal filtration method and the values of removal percentage of phenol (R %) were conducted from difference initial concentrations ( $C_o$ ) and the equilibrium concentration of phenol (C). The removal percent (R %) was obtained using equation (2-1).

$$R\% = \frac{C_o - C}{C_o} * 100 \quad (2.1)$$

Where:

R is the percent of phenol removal

$C_o$  is initial concentration

C is the equilibrium adsorbate phenol concentration

## 3. Result and discussion

### 3.1. Calibration curve

The calibration curve (was utilized to obtain the concentration of phenol remaining after the extraction process.

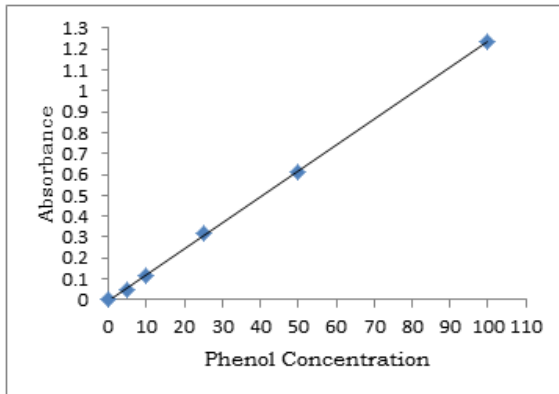
**Table 3.1:** The concentration verses absorbance of phenol

| C phenol (ppm) | Absorbance |
|----------------|------------|
| 0              | 0          |
| 5              | 0.045      |
| 10             | 0.114      |
| 25             | 0.317      |
| 50             | 0.611      |
| 100            | 1.231      |

**Table 2.1:** The properties of used absorbents

| Absorbent Name   | Formula | Type of Absorbent | Source/Location     |
|------------------|---------|-------------------|---------------------|
| Activated Carbon | AC      | Organic           | SEED-HANNOVER       |
| Local Coal       | LC      | Organic           | Local Product       |
| Silica Gel       | SG      | Chemical          | SEEDEL-HANNOVER     |
| Local Sand       | LS      | Mineral           | Natural Pro- Zliten |
| Bentonite        | Be      | Mineral           | Natural Pro- Tobruk |
| Carpentry        | Ca-     | Organic           | Natural Pro-        |

All of these absorbent were sieved to particles size of 500 micron.

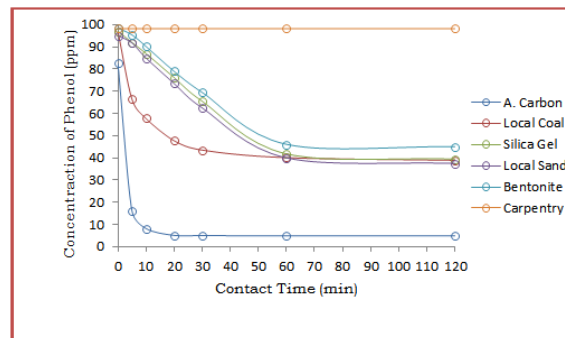


**Figure 3.1:** The relationship between concentrations and absorbance of phenol.

### 3.2. Effect of contact time

Contact time is an essential factor to obtain the equilibrium time of adsorption process [10]. Figure (3.2) shows the results for determination of equilibrium time which is clearly seen that each adsorbent material has a slight different adsorption capacity. The result as showed fast phenol removed by Activated Carbon within the first 10 minutes, and the equilibrium was reached after 20 minutes. The desorption results using the local coal shoed the same adsorption behavior, but with a lower adsorption capacity. Noticeably, in the case of Local Sand as well as Silica Gel, the amount of phenol left had a small decrease and both reached the equilibrium time after 1 hour. Moreover, the bentonite had less capacity of phenol removed which is about (56.5 ppm). Interestingly, Carpentry has a distinguish result, where the amount of phenol left was fixed along the time. In summary, the effect of contact time has a similar result with the adsorbent dosage. The obtained results demonstrated that the removal percent (R %) of phenol increases with the in-

crease in contact time (t). The results are in good agreement with reported results in literature [11, 12].



**Figure 3.2:** Effect of contact time on phenol uptake.

### 3.3. The effect of dosage

Figure (3.3) shows the effect of adsorbent dose on the removal of phenol for initial phenol concentration (100 ppm) with constant optimum pH value about 7 and zero contact time. The result demonstrated that the removal percentage (R %) of phenol increases with the increase in the adsorbent dosage. The increase in the removal percentage is attributed to the increase in the adsorbent surface area and availability of more adsorption sites caused by the increasing adsorbent dose. These investigations are in agreement with literature [13].

### 3.4. Adsorption Isotherms

#### 3.4.1. Freundlich isotherm

In this work Langmuir and Frenlich isotherms were used to describe the relation between the amount of phenol and its equilibrium concentrations as showed in figure below. The linear form of Freundlich isotherms is given by equation (3.1)



**Table 3.2:** The change in the concentration of phenol by increasing of the contact time.

| Contact Time (min) | Activated Carbon | Local Coal | Silica gel | Local Sand | Bentonite | Carpentry |
|--------------------|------------------|------------|------------|------------|-----------|-----------|
| 1                  | 82.5             | 97.1       | 97.1       | 95.1       | 98.5      | 98.2      |
| 5                  | 16.25            | 66.5       | 92         | 91.8       | 95.4      | 98.2      |
| 10                 | 8.19             | 57.75      | 87         | 85         | 90.2      | 98.2      |
| 20                 | 4.95             | 47.75      | 76.2       | 73.5       | 79        | 98.2      |
| 30                 | 5                | 43.5       | 65.5       | 62.5       | 69.5      | 98.2      |
| 60                 | 4.9              | 40.1       | 41.8       | 40         | 46.1      | 98.2      |
| 120                | 4.88             | 38.9       | 39.5       | 37.5       | 45.1      | 98.2      |

**Table 3.3:** The changes in concentration of phenol by increasing the amount of adsorbates.

| Dosage | Activated Carbon | Local Coal | Silica Gel | Local Sand | Bentonite | Carpentry |
|--------|------------------|------------|------------|------------|-----------|-----------|
| 0.5    | 68.5             | 58.9       | 58.2       | 60.9       | 56.5      | 65.7      |
| 1      | 70.95            | 60.5       | 59         | 62.2       | 57.6      | 67.176    |
| 1.5    | 72.81            | 61.25      | 60.13      | 62.55      | 58.8      | 68.06     |
| 2      | 74               | 62.25      | 60.8       | 63.5       | 59.21     | 68.26     |
| 2.5    | 75               | 63.5       | 61.5       | 64.5       | 60.5      | 68.76     |
| 3      | 75.6             | 63.9       | 62.2       | 65         | 60.9      | 68.8      |

$$\log A = \log K + \frac{1}{n} \log C \quad (3.1)$$

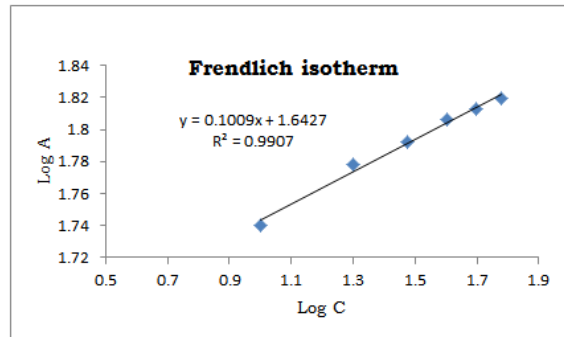
Where

- A is the phenol adsorption
- K is adsorption capacity
- C is concentration of phenol n is adsorption intensity

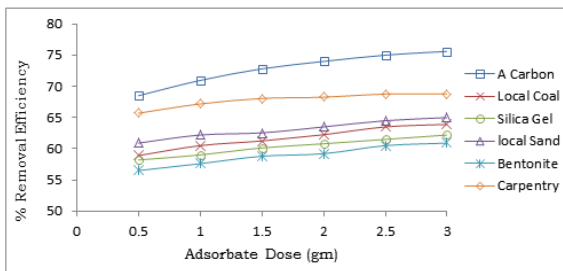
The leaner form of Langmuir isotherm can be written as follows:-

$$\frac{1}{A} = 1 + \frac{1}{KC} \quad (3.2)$$

Where simples are already mentioned.



**Figure 3.4:** Freundlich isotherm for phenol adsorption on activated carbon.

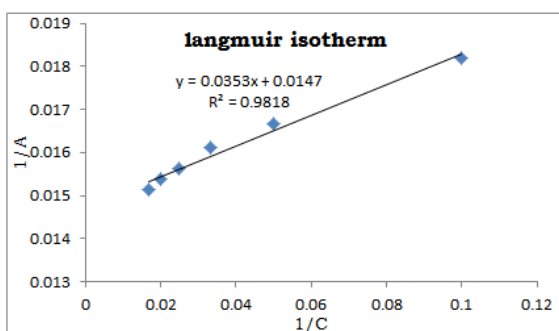


**Figure 3.3:** Effect of adsorbent dose on removal efficiency at initial phenol concentrations.

**Table 3.4:** The concentration of activated carbon by using Freundlich isotherm .

| C  | A  | log C | log A | 1/C   | 1/A   |
|----|----|-------|-------|-------|-------|
| 10 | 55 | 1     | 1.74  | 0.1   | 0.018 |
| 20 | 60 | 1.30  | 1.77  | 0.05  | 0.017 |
| 30 | 62 | 1.48  | 1.79  | 0.03  | 0.016 |
| 40 | 64 | 1.60  | 1.80  | 0.025 | 0.016 |
| 50 | 65 | 1.69  | 1.81  | 0.02  | 0.015 |
| 60 | 66 | 1.78  | 1.82  | 0.017 | 0.015 |

### 3.4.2. Langmuir isotherm



**Figure 3.5:** Langmuir isotherm for phenol adsorption on activated carbon.

## 4. Conclusion

Pollution of water by phenolic compounds is considered tremendously hazardous to the environment. The experimental results demonstrate the variation of adsorbent materials that may use in removal of phenol. The result indicated that the percentage removal of phenol was influenced by amount of adsorbent dose, initial concentration and contact time. The Langmuir and Freundlich adsorption models were used for the mathematical description of the adsorption model. The obtained results showed that the adsorption equilibrium data fit very well to Freundlich model.

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