

A Comparison Study on the Removal of Phenol from Aqueous Solution Using activated carbon

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Abstract— In this research we will study the potential of activated carbon for the removal of phenol. Batch kinetics and isotherm studies and thermodynamic parameters were carried out to evaluate the effects of contact time (t), phenol initial concentration (C₀), adsorbent dose (C_{ads}), and pH of the solutions. the aim of this study is the removal of phenol ions from aqueous solution by activated carbon . We are investigating the impact of various experimental factors such as contact time, initial concentration, adsorbent dosage, temperature and pH of phenol solution.

Index Terms—phenol removal, organobentonite, wastewater treatment, cetyl tri methyl ammonium bromide, cetyl pyridinium chloride.

1. Introduction

Water is an influential and fundamental component of this world and plays a crucial role in the suitable operating of the Earth's ecosystems. Not with standing this, safe drinking water is not available in some local environment of the world. The characteristic of water resources is spoil exponentially because of their pollution. Water pollution by heavy metals has accepted wide expansion concentration for many decades and has been a major cause of affect due to production of a high toxicological risk for ecosystem, agriculture, and human health.

Adsorption process is the physical adhesion of the polluting chemicals onto the surface of a solid. A wide range of materials for water remediation have actually been employed in recent years. These include activated carbon, bentonite, peat, sand, coal, fiberglass, polypropylene, amberlite, organoclay, and attapulgite [1]. Water pollution by organic chemicals is a major problem over decades. The removal of organic contaminants from ground water or separation of contaminants present in polluted water has become a major focus of research and policy debate [2]. The presence of harmful organic compound such as phenols and their derivatives in water supplies and from industrial effluents is an ever increasing problem for the global concern [3]. Widespread contamination of wastewater by organic pollutant has become a recognized problem of global importance in recent years. The WHO [world health organization] recommends a permissible phenolic concentration of 0.001 mg/L in potable water [4,5]. Removal of phenol from industrial effluents is an important and dynamic area of research as well as being an important challenge, because environmental laws and regulations governing safe discharge levels are becoming increasingly stringent [6]. Phenol is an aromatic hydrocarbon have been of the benzene derivatives. Its solubility in water, 93-98 g/L, and depends on the water temperature (20 to 25°C). Phenols are weak acidic characteristics. Phenols are present in wastewater of various industries, such as oil refineries (6–500 mg/L), coking operations (28–3900 mg/L), coal processing (9–6800 mg/L), and petrochemicals plants (2.8–1220 mg/L), plastic industry, textile processing, leather processing, insecticides production, wood products, paint, pulp and paper industries within 0.1– 1600 mg/L concentrations manufacture of dyes and dyeing,

glass production, etc [7]. MOEF [Ministry of Environment and Forests] considered the maximum concentration 1 g/L for surface water and industrial output. The maximum allowable concentration in the Phenol discharge to the surface water and irrigated agriculture is 1 g/L [8], so the removal of phenol from industrial wastewater, will be necessary before discharging to the water flow. For filtration of wastewater containing phenol, there are several methods, such as adsorption, chemical oxidation (using oxidizing materials such as UV radiation, chlorine and hydrogen peroxide), advanced oxidation (such as using O₃/UV or TiO₂/UV) and biological treatment [9]. Phenol of the chemical formula C₆H₅OH, after release in the environment, have not a long half-life, but as a result of sustained release, will increase permanence time in water, soil and air. To be classified as destructive methods such as oxidation with ozone and healing methods such as absorbed in the pores of a solid adsorbent. Survey research indicates that a large number of adsorbents such as activated carbon, coal, ash, sugar cane, bran peel and agricultural waste been used as potential adsorbent [10]. Adsorption method is expensive due to the use of activated carbon adsorbent, so should will have to replace adsorbents with cheap and plentiful materials. So far, many studies have investigated the use of non-conventional low-cost adsorbents, like bentonite, kaolinite, and zeolite organic soils, agricultural waste such as almond skin, peach kernel, kernel and wood palm, bagasse, rice husk and grasses various [11].

Phenol is toxic and due to their non- biodegradability and continuation, they predisposed to collect in living organisms causing various sickness. Phenol is example of metals that are causing damage wastes produced by industries which display a hazard of polluting groundwater and other water resources.

Exposure to phenol may occur from the use of some medicinal products (including throat lozenges and ointments). Phenol is highly irritating to the skin, eyes, and mucous membranes in humans after acute (short-term) inhalation or dermal exposures. Phenol is considered to be quite toxic to humans via oral exposure. Anorexia, progressive weight loss, diarrhea, vertigo, salivation, a dark coloration of the urine, and blood and liver effects have been reported in chronically (long-term) exposed humans. Animal studies have reported reduced fetal body

weights, growth retardation, and abnormal development in the offspring of animals exposed to phenol by the oral route. EPA has classified phenol as a Group D, not classifiable as to human carcinogenicity.

Inhalation and dermal exposure to phenol is highly irritating to the skin, eyes, and mucous membranes in humans. Symptoms of acute toxicity in humans include irregular breathing, muscle weakness and tremors, loss of coordination, convulsions, coma, and respiratory arrest at lethal doses.

The adsorption appears to be an attractive select for phenol removal for its efficiency of removal and for the rapid adjustment to pollutant loading modification. However activated carbon as adsorbent has been greatly used for the treatment of phenol containing wastewaters.

Adsorption is one of the effective, simple, economic methods and useful for the removal of the phenol. It is a terrible need of a treatment method for phenol removal which is inexpensive, simple and effective. Adsorption when integrated with a suitable step of desorbing the adsorbate from adsorbent and preventing the problem of arranging of adsorbent is a cost effective and changeable method for the removal of phenol.

The advantages of the adsorption process quick to give the use of other materials with structural, constitutional or chemical characteristics suitable to make his technique with high phenol maintenance values and it has high potential for the phenol removal from wastewater streams. It means that the selection of an adsorbent is a key factor for the use of adsorption as a treatment technique for phenol removal. The cost connected with commercial adsorbents make adsorption process very expensive which has arrives to the search for new strategies for developing low-cost materials with a good capacity for phenol removal. The aim of this research is to study the adsorption capacity of activated carbon for the removal of phenol from water.

2. EXPERIMENTATION

Analytical-reagent grade phenol (hydroxybenzene or carboic acid, CAS No.: 108-95-2) (purchased from Sigma-Aldrich) was used as the adsorbate. Commercial activated carbon (AC, untreated, granular, CAS No.: 7440-44-0) (supplied by Sigma-Aldrich was used as adsorbent, These chemicals were used without further purification.). A stock solution of desired concentration was prepared by dissolving the required amount of phenol in double-distilled water. Working solutions of the desired concentrations in different phases of the study were obtained by successive dilutions. FTIR data were obtained using Bruker Model Vertex 70 FTIR spectrometer coupled to Platinum ATR unit using spectral range of 4000–400 cm^{-1} , Bruker, Germany. The specific surface area, and pore volume were determined by means of N_2 adsorption desorption isotherm measurements under temperature of liquid nitrogen using BELSORP mini-II, BEL Japan, INC, at 77K as adsorption temperature, and saturated vapor pressure of 89.62 kPa. The samples were pre-treated at 105 °C under flow of nitrogen gas. Exact surface area, pore

diameter, and pore volume were calculated from the nitrogen adsorption isotherms based on Brunauer, Emmett and Teller (BET) theory [ref] from the liner part of the adsorption isotherm at pressures between 0.05 and 0.30.

2.1. Adsorption experiments

In adsorption equilibrium, experiments were conducted in a set of 250 mL Erlenmeyer flasks, containing 100 mL of solution, with different initial concentrations of 10 to 50 mg/L using 0.35 g of activated carbon was added to phenol solutions and each sample was left 6 h to reach equilibrium. Temperature and pH of the solutions were not controlled. The initial and final concentrations of phenol in the solutions were determined using UV-VIS spectrometer (Unicam 8700). This method was based on the color developed as a result of the reaction of phenol with 4-aminoantipyrine as detailed in the standard methods [14]. In order to minimize the interference of the adsorbents with the analysis, the samples were centrifuged at 800 rpm for at least 15 min. After that, the supernatant was filtered through a 0.45- μm filter paper. All experiments were duplicated under identical conditions. The amount of adsorption at equilibrium, q_e (mg/g), was calculated using Equation 1:

$$q_e = \frac{C_0 - C_e}{M/V} \quad (1)$$

where C_0 and C_e (mg/L) are the initial and equilibrium concentrations of phenol, respectively. V (L) is the volume of the solution and M (g) is the mass of the adsorbents.

3. Results and Discussion

3.1. Characterization of the adsorbents

In order to obtain information about the mode of interaction of activated carbon with phenol, different physico-chemical measurement was carried out .

3.2. Fourier Transform Infrared Spectrometer (FTIR)

The spectrum of activated carbon are usually compared with that of the phenol-activated carbon species to achieve an idea about the groups interact with the phenol. Fig. 1 represents the FTIR of the bentonite pure alone compared with the IR spectrum after adsorption acivated carbon species in Fig. 2 .

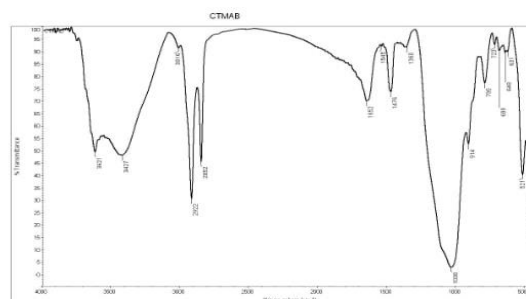


Fig. 1: FTIR spectra before adsorption of phenol by activated carbon.

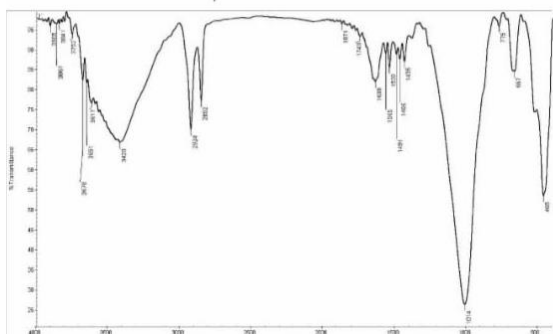


Fig. 2 : FTIR spectra after adsorption of phenol by activated carbon

3.2. Parameters

3.2.1. Effect of Contact Time and Initial Phenol Concentration

The effect of contact time for adsorption process was carried out to determine the equilibrium point for a period of 0 - 60 min for activated carbon with different initial phenol concentrations (Fig. 3). The other parameters of the study were kept constant. It was found for all sets of Based on the Fig. 3, the necessary time to reach equilibrium was variable and depended on the initial concentration of the phenol, which was increased with the increases of initial concentration and was about 30 min and 50 min for C₀ of 10 and 20 mg/L for activated carbon, respectively. It should be noted that the more the initial phenol concentration the more would be the adsorption capacity of adsorbents, but the adsorption efficiency of

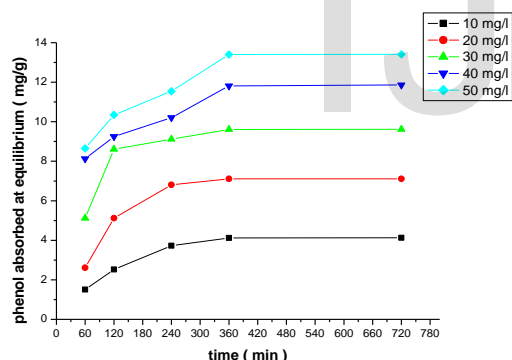


Fig. 3. The effect of contact time for activated carbon with different initial phenol concentrations

3.2.2. Effect of pH

Hydrogen ion concentration of the solution plays an important role in the adsorption processes [18,19,20]. The effect of pH on the adsorption capacity of phenol was shown in Fig. 4. At higher pH, adsorption of activated carbon was greater which might be explained on the assumption that activated carbon covered with positive charges and increased electrochemical interaction between phenol molecules and the activated carbon surfaces [19,20]. The ionization degree of phenol depends on the pH values of the solution. If pH of the solution was more than the pK_a of phenol (≈ 9.92), phenol would disso-

experiments that the adsorption was rapid in the initial stages of the process because of higher driving forces resulted from the largest amount of phenol [14] and later it became slow, and finally the systems reached equilibrium after around 60 and 360 min for activated carbon. The adsorbed amount (mg/g) increased with longer contact time until it reached equilibrium and the curves of phenol adsorption with respect to time got smooth and continuous indicative of saturation. As shown in Fig. 5, the required time to reach equilibrium was selected as the contact time for further experiments of activated carbon.

adsorbent was inversely related to the initial phenol concentration and the removal efficiencies decreased as the concentration increased at a fixed adsorbent dosage [16,17]. The results showed that an increase in initial phenol concentration would lead to a decrease in the rate of constants values, which are in agreement with the study of Benguella and Benaissa [17].

ciate to negatively charged species such as C₆H₅O⁻, which could be easily adsorbed on positively charged activated carbon surfaces and favored in higher pH values. But when the pH was lower than pK_a, more electrostatic repulsions would decrease phenol adsorption due to the more availability of protons [21]. As clearly seen in Fig. 4, when the pH is lower than 7, activated carbon has more removal efficiency as its particles have active sites with negative charges at relatively acidic pH and phenol was undissociated. Hence, the dispersion interaction predominated. Furthermore, the higher concentration of H⁺ ions within low solution pH can neutralize those negative sites, reduces the hindrance to diffusions of phenol ions from the aqueous solution and consequently increases the chances of their adsorption. However, at the high solution pH, OH⁻ concentration ions dominates, which can in turn increase the hindrance to the diffusions

of phenol ions and thus reduce the chances of their adsorption [22,23]. Therefore, based on the experimental results, pH values of 7 were selected as the optimum

values for further experiments on activated carbon, respectively.

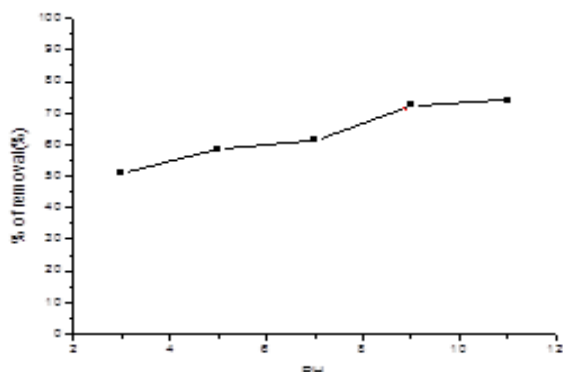


Fig. 4. Effect of pH of the solution on the phenol adsorption by, shaking time = 360 min, C₀ = 50 mg/L and b) activated carbon: dose = 0.4 g/L, shaking time = 60 min, C₀ = 50 mg/L.

3.2.3. Effects of adsorbent dosages

The adsorbent dose is an important parameter in adsorption studies because it determines the capacity of adsorbent for given concentration of phenol. The adsorption was investigated by taking the following values as constant: room temperature = 25 °C, concentration = 1 ppm, pH 7, contact time = 6 h for activated carbon, and room temperature = 25 °C, concentration = 1 ppm, shaking speed 240 rpm.

The variations of dose from 0.1 g to 0.5 g for adsorbent are graphically represented in Fig. 5. The mass seems to exert an important influence on the adsorption process. The optimum dose was observed with removal at 0.35 g, 0.1 g at percentage removal 77.6% of phenol by activated carbon .

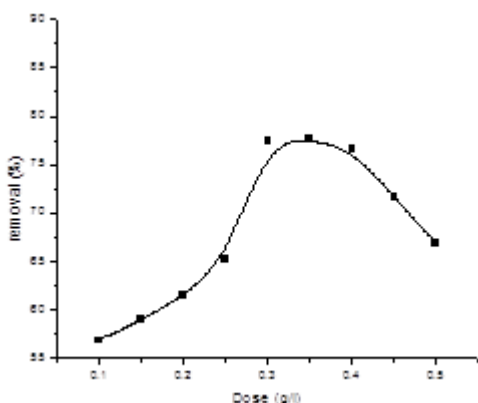


Fig. 5: Effect of adsorbent dosage on the adsorption of phenol by activated carbon .

4. Conclusion

The present work shown that activated carbon a promising low cost adsorbent to be used in the removal of phenol

from aqueous solutions over a wide range of concentrations. FTIR was used to made characterization of activated carbon and response surface methodology was used to investigate the interactive effect of the adsorption process.

The influence of various experimental factors such as contact time, initial phenol concentration, adsorbent dosage, temperature and pH of phenol solution were optimized.

The experimental results showed that the adsorptive removal of phenol decreased with increasing the temperature for each of activated carbon ,the adsorptive removal were increased with increasing pH, contact time. The optimum pH found after adsorption experiments was pH = 7 for activated carbon.

The experimental results showed that the adsorptive removal of phenol increased with increasing the contact time at 6 hr. for activated carbon

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