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Use of Food Waste Activated Carbons for Wastewater Treatment

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Use of Food Waste Activated Carbons for Wastewater Treatment

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A Thesis
Submitted in Partial Fulfillment of the
Requirements for the Degree of
Bachelor of Science in Chemical Engineering
As an Honors Scholar

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4 Abstract

Activated carbons are often used to remove phenol from wastewater. However, they are usually derived from expendable resources, such as coal and have high regeneration costs (Mishra S. et al., 2019). In this work, the adsorption of phenol on activated carbon derived from food waste was studied to understand its kinetics, determine its maximum adsorption capacity, and compare it to commercial activated carbons. Adsorption experiments were performed at 298 K for 48 hours at various pHs and initial phenol concentrations. The adsorption data was then fit to the pseudo-first order, pseudo-second order, and intraparticle diffusion models to understand the kinetics and to the Langmuir and Freundlich isotherm models to determine the maximum adsorption capacity. The results show that the adsorption process on activated carbons derived from food waste is best described by the pseudo-second order and Langmuir models. The maximum adsorption capacity of these activated carbons is 46.30 mg/g, which is comparable to the value for commercial activated carbons. This work shows that activated carbon derived from food waste is a potential alternative to commercial activated carbons in wastewater treatment.

5 Introduction

Phenol is an important raw material used in many industries, such as oil, resin, plastic, textile, and pharmaceutical (Anku et al., 2016). However, the wastewater they produce is often discharged into bodies of water without treatment, impacting the health of humans and the environment. Phenol is a primary pollutant and only needs to exist in small amounts (9–25 mg/L) to exhibit toxic health effects on humans and animals (Environmental Protection Agency, 2017; Kulkarni et al., 2013). Some health effects on humans include irregular breathing, muscle weakness, tremor, coma, and respiratory arrest, while effects on animals include irritation of liver, kidney, and cardiovascular tissues (Villegas et al., 2016). Additionally, phenol tends to accumulate in the environment over an extended period of time (Anku et al., 2016). It is also soluble in water, making it difficult to bring its concentration below the permissible limit of 1 mg/L in wastewater (Xie et al., 2020). For these reasons, several techniques have been developed to remove phenol from wastewater and mitigate these effects.

Commercial activated carbons (CAC) are commonly used for wastewater treatment due to their high surface areas, large pore volumes, and high surface reactivity. They remove pollutants, including phenol, through adsorption. In adsorption, adsorbates (phenol molecules) are attracted by the surface of the adsorbent (activated carbon) and adhere to it by physisorption or chemisorption. Physisorption involves intramolecular forces, while chemisorption relies on valence forces.

Although CAC are highly effective in phenol removal, they are also expensive due to the cost of raw materials and regeneration (Mishra S. et al., 2019). In response to this, many researchers have synthesized activated carbons made from agricultural and food waste, such as corn husks, coconut shells, date pits (Mishra S. et al., 2019; Singh et al., 2008; Banat et al., 2004). Because these wastes are so accessible, the cost of the adsorbent is reduced.

Activated carbons derived from food waste collected from UConn dining halls (FWAC) have been shown to be promising candidates for water purification (Yu et al., 2020). They are

synthesized by pyrolysis and physical activation. Pyrolysis heats the food waste in the absence of oxygen, decomposing it into biochar, bio-oil, and syngas. The biochar is then activated using steam to form activated carbon.

The objectives of this work are to study the adsorption process of phenol on FWAC and determine if FWAC are a viable alternative to CAC in wastewater treatment. Adsorption experiments were performed at various pHs to determine the optimal condition and at different initial phenol concentrations (10, 20, and 30 mg/L) to simulate a toxic environment (9–25 mg/L). The experiments were performed at room temperature (298 K) and ran for 48 hours. The adsorption data was then fit to kinetic models to identify the mechanism of adsorption and the processes that control adsorption on FWAC. The data was also fit to isotherm models to determine the amount of phenol FWAC can adsorb or the maximum adsorption capacity. Finally, this value was compared to values in literature to see if FWAC are a viable alternative to CAC in wastewater treatment.

6 Materials

NaOH and H₂SO₄ were used to adjust pH. Phenol was used as the adsorbate and mixed with distilled water. Methanol was used to absorb bio-oil in pyrolysis. All chemicals were purchased from Sigma-Aldrich. CAC provided by Cabot Corporation and FWAC prepared in Valla Lab were used as adsorbents. Ar provided an inert atmosphere during pyrolysis, while N₂ was used to carry steam during activation; both were purchased from Airgas.

6.1 Preparation of FWAC (Yu, et al., 2020)

Food waste collected from the Department of Dining Services at UConn was first pretreated for pyrolysis and physical activation. It was washed with DI water five times to remove salt and soluble minerals. Then, it was crushed into small pieces, ground up, and sieved to obtain a particle size between 180 and 335 μm .

After, the pretreated food waste was pyrolyzed to produce biochar. The pretreated food waste was placed in between two pieces of quartz wool and then in the center of a quartz tube. The filled tube was inserted into a vertical tube furnace, where it was heated from 275°C to 525°C at a ramp rate of 10°C/min for 120 minutes. During this process, Ar gas was flowed through the furnace at 50 sccm to create an inert atmosphere, while cooled methanol was used to absorb bio-oil. After pyrolysis, the biochar was ground and sieved to obtain a particle size less than 300 μm .

The last step in preparing food waste activated carbons is the physical activation of the biochar. This is done by putting biochar into an alumina boat and heating it in a horizontal tube furnace. The biochar was heated from 750°C to 1050°C at a ramp rate of 10°C/min for 5 hours. During this process, N₂ was flowed through the furnace at 50 sccm to carry steam a saturator. The partial pressure of steam was kept at approximately 50% using a temperature controller.

7 Methods

7.1 pH Experiments

Batch experiments were performed to determine the optimal pH for phenol adsorption. First, a 20 mg/L phenol solution was prepared. Its pH was measured to be 8.63. Then, varying amounts of 0.05 M H₂SO₄ and 0.10 M NaOH were added to the initial phenol solution to adjust the pH to around 3, 5, 6, and 12. For each pH adjustment, 50 mL of solution and 10 mg of CAC were stirred together at 200 rpm for 48 hours. All experiments were performed at room temperature (298 K). After adsorption, the mixtures were filtered to remove CAC from the solutions. Filtrates were then analyzed by UV-vis (Perkin Elmer UV/VIS spectrometer Lambda 35) to determine the equilibrium concentrations of phenol (C_e , mg/L). With C_e , the amount of phenol absorbed at equilibrium (q_e , mg/g) can be calculated using the following equation:

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

where: C_0 is the initial concentration of phenol (mg/L), V is the volume of phenol solution added (L), and m is the mass of activated carbon (g).

7.2 Phenol Adsorption Experiments

A similar procedure was performed to determine the effects of initial adsorbate concentration and contact time on adsorption. The initial concentrations tested were 10, 20, and 30 mg phenol/L. For each concentration, the phenol concentration was measured at times 0.5, 1, 2, 3, 4, 6, 8, 16, 24, and 48 hours. For each time, a separate adsorption experiment was performed.

In each experiment, 10 mg of activated carbon was added to 50 mL of prepared phenol solution. Then, the mixture was stirred at 200 rpm at 298 K for the desired time. After, the mixture was filtered and analyzed by UV-Vis. Similar to Equation (1), the amount of phenol absorbed at time t (hours) (q_t , mg/g) can be calculated using the following equation:

$$q_t = \frac{(C_0 - C_t)V}{m} \quad (2)$$

where: C_t is the concentration of phenol at time t (mg/L), C_0 is the initial concentration of phenol (mg/L), V is the volume of phenol solution added (L), and m is the mass of activated carbon (g).

The amount of phenol absorbed at equilibrium (q_e , mg/g) was also calculated using Equation (1).

To determine the removal efficiency of phenol by FWAC and CAC, the following equation was used:

$$Removal(\%) = \frac{C_0 - C_e}{C_0} * 100\% \quad (3)$$

where C_0 and C_e are the initial and equilibrium concentrations of phenol (mg/L), respectively.

Due to university closure caused by the COVID-19 pandemic, all adsorption experiments could not be completed. Experiments for FWAC were completed, but only one concentration was tested for CAC (20 mg/L). For this reason, the model analysis and results described in the following sections focus on adsorption on FWAC.

7.3 Adsorption Equilibrium Models

Data collected from the phenol adsorption experiments were fitted to the Langmuir and Freundlich isotherm models to understand the interaction between the adsorbate and adsorbent surface. These models were selected, as they are commonly used to study adsorption behavior. The Langmuir model is a theoretical model that assumes that a monolayer forms on the adsorbent surface. This means that only one phenol molecule can be adsorbed per adsorption site and that maximum adsorption or equilibrium will be reached. It also assumes that the surface is homogenous with identical adsorption sites. In contrast, the Freundlich model is an empirical model that does not assume monolayer adsorption and suggests that the surface is heterogenous.

The linear forms of these models are shown below (Langmuir, 1916; Freundlich, 1906):

$$\text{Langmuir isotherm model: } \frac{C_e}{q_e} = \frac{C_e}{q_m} + \frac{1}{K_L q_m} \quad (3)$$

$$\text{Freundlich isotherm model: } \log(q_e) = \frac{1}{n} \log(C_e) + \log(K_F) \quad (4)$$

where: q_e is the amount of phenol absorbed at equilibrium (mg/g), C_e is the equilibrium concentration of phenol (mg/L), and q_m is the maximum adsorption capacity (mg/g). K_L is the Langmuir constant related to the energy of adsorption (L/mg), while K_F and $\frac{1}{n}$ are Freundlich model constants related to adsorption capacity (mg/g) and adsorption intensity (unitless), respectively.

K_L and q_m were determined by plotting $\frac{C_e}{q_e}$ vs. C_e , while K_F and $\frac{1}{n}$ were determined by plotting $\log(q_e)$ vs. $\log(C_e)$.

To better understand the significance of the Langmuir constant (K_L), the separation factor R_L was calculated, as shown below by Equation 5 (Rahman and Islam, 2009).

$$R_L = \frac{1}{1 + K_L C_0} \quad (5)$$

R_L predicts the affinity between the adsorbate and the adsorbent (Jeong, et al., 2020). Its value indicates whether adsorption is favorable ($0 < R_L < 1$), unfavorable ($R_L > 1$), linear ($R_L = 1$), or irreversible ($R_L = 0$).

The Freundlich constant, $\frac{1}{n}$, measures the heterogeneity of the adsorbent surface. The surface is more heterogenous if $\frac{1}{n}$ is closer to 0.

7.4 Adsorption Kinetic Models

The data was also fitted to the following kinetic models to study the mechanism of adsorption and the potential rate controlling steps (Lagergren, 1898; Ho and McKay, 1999; Weber and Morris, 1963):

$$\text{Pseudo-first order model: } \ln (q_e - q_t) = \ln (q_e) - k_1 t \quad (5)$$

$$\text{Pseudo-second order model: } \frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{1}{q_e} t \quad (6)$$

$$\text{Initial rate of adsorption: } h_0 = k_2 q_e^2$$

$$\text{Intraparticle diffusion model: } q_t = k_3 t^{1/2} + I \quad (7)$$

where: q_e is the amount of phenol absorbed at equilibrium (mg/g) and q_t is the amount absorbed at time t (mg/g). k_1 , k_2 , and k_3 are the rate constants for pseudo-first order (hour^{-1}), pseudo-second order (g/mg/hour), and intra-particle diffusion ($\text{mg/g/hour}^{1/2}$), respectively. The rate constants were determined by plotting $\ln (q_e - q_t)$ vs. t , $\frac{t}{q_t}$ vs. t , and q_t vs. $t^{1/2}$.

Pseudo-first order and pseudo-second order are reaction-based models. These models were selected since they are frequently used to study the adsorption kinetics of pollutants and quantify the extent of uptake in adsorption (Gautam and Chattopadhyaya, 2016). If the data best fits the pseudo-first order model, phenol adsorption is controlled by physisorption, but if it best fits the pseudo-second order model, phenol adsorption is controlled by chemisorption (Ho and McKay, 1999).

The intraparticle diffusion model was also selected to identify the diffusion mechanism. An adsorption process is dependent on intraparticle diffusion if the plot of q_t vs. $t^{1/2}$ results in a straight line passing through the origin. If the data fits to multiple lines, this means that two or more steps control the adsorption process. The steps include film or external diffusion, pore diffusion, surface adsorption, or a combination of them (Srivastava et al., 2005). These steps are described by intercept I of the intraparticle diffusion model. The larger it is, the greater the boundary layer effect (McKay, et al., 1990). If it is positive, rapid adsorption occurs.

8 Results and Discussion

8.1 Effect of pH

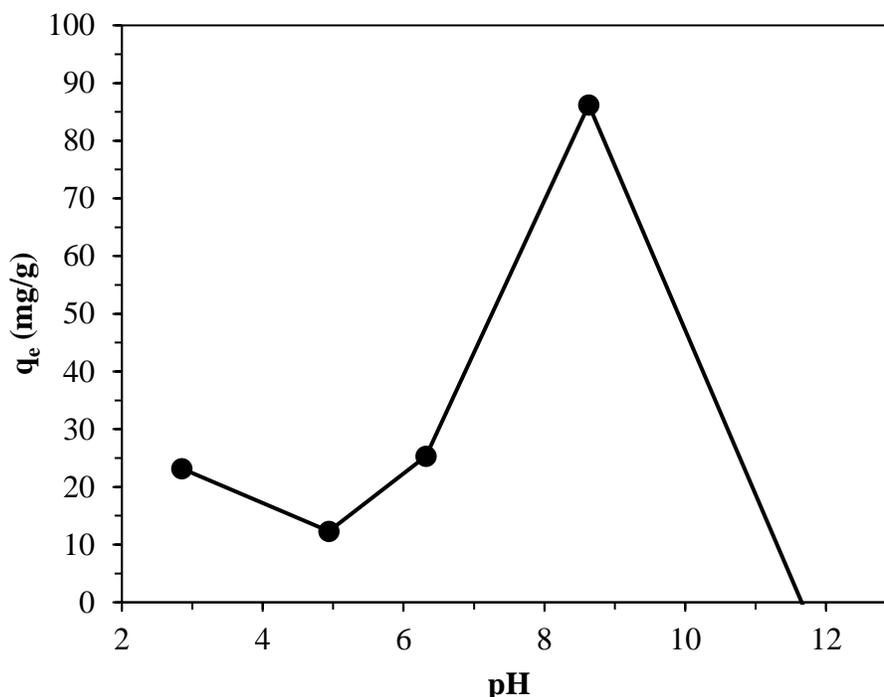


Figure 1. Amount of phenol adsorbed at equilibrium (q_e) on CAC versus pH.

The pH of the phenol solution affects adsorption, as it controls electrostatic interactions between activated carbon and phenol. As shown by **Figure 1**, the optimal pH for phenol adsorption is 8.63. This is the pH of the initial phenol solution with no H_2SO_4 or NaOH added. For this reason, the pH of the phenol solution was not adjusted in the adsorption experiments.

Phenol adsorption decreases significantly when the pH is above and below 8.63. This may have occurred due to leaching. During the pH experiments, the filtrates at an adjusted pH (2.85, 4.94, 6.32, and 12.06) were observed to be darker in color, suggesting that carbon leaching may have occurred. Leached solutes may have been adsorbed back onto the activated carbon, decreasing the available sites for phenol. Furthermore, the solution at 12.06 may have experienced the most leaching since it was the darkest and thus explain why q_e at this pH is negative.

Phenol adsorption may have also decreased due to electrostatic interactions. At $\text{pH} < 8.63$, the surface of CAC may have been positively charged due to the presence of more H^+ ions. Phenol is a weak acid with a $\text{p}K_a = 9.99$ at 298 K, meaning that phenol is undissociated or non-ionized at acidic conditions (National Center for Biotechnology Information, n.d.). However, undissociated phenol prefers negatively charged surfaces (Ulker, et al., 2009). Phenol also competes with water, further decreasing phenol adsorption (Xie, et al., 2020, Ulker, et al., 2009). Similarly, at $\text{pH} > 8.63$, phenol adsorption decreased due to electrostatic repulsions. When $\text{pH} > \text{p}K_a$, phenol dissociates into phenolate ($\text{C}_6\text{H}_5\text{O}^-$) and interacts with the potentially negatively charged surface of CAC. Electrostatic repulsions also occur between OH^- and phenolate. However, during the

experiments, the final pH should have been measured to determine the pH at point of zero charge (pH_{PZC}). pH_{PZC} would confirm the surface charge of CAC at acidic/basic conditions and the electrostatic interactions described above.

8.2 Phenol Adsorption on FWAC and CAC

8.2.1 Effect of initial concentration of adsorbate on adsorption

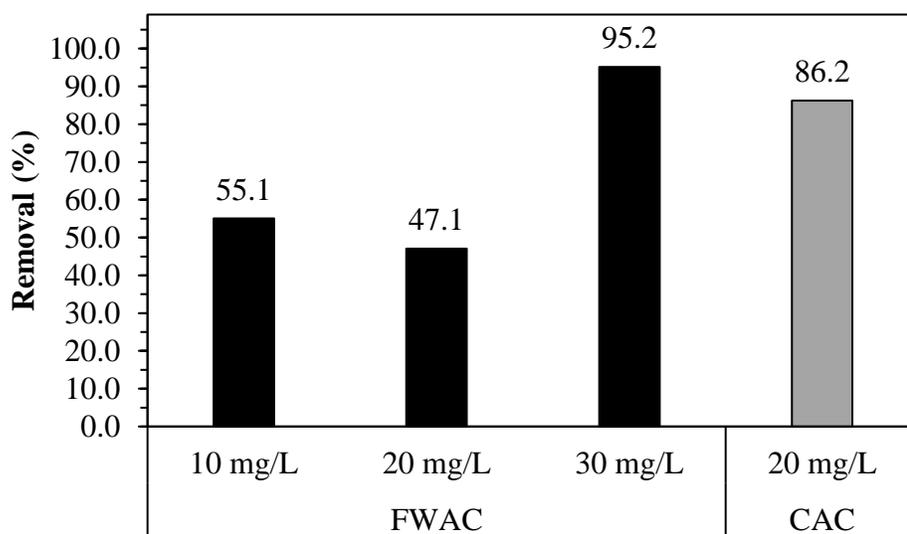


Figure 2. Phenol removal efficiencies (%) of FWAC (black) when initial phenol concentrations are 10, 20, and 30 mg/L and of CAC (grey) when initial concentration is 20 mg/L.

Generally, removal efficiency decreases when initial concentration of adsorbate increases (Afsharnia et al., 2016; Mishra S. et al., 2019). At higher concentrations, there is more phenol present, saturating activated carbon faster and thus decreasing efficiency. This trend is observed when the initial phenol concentration is increased from 10 mg/L to 20 mg/L on FWAC, as shown in **Figure 2**. However, when the initial concentration is 30 mg/L, removal efficiency of FWAC increases to 95.2%. Other researchers have shown that removal efficiency should be the lowest at 30 mg/L (Mishra IM et al., 2019). This increase in efficiency may have occurred since we used a different batch of FWAC for this concentration. This batch may have had a higher adsorption capacity than the batch used for 10 mg/L and 20 mg/L. Experiments should be performed again using the same batch of FWAC. Also, the removal efficiency of FWAC at 30 mg/L should have been much lower since it should be less than the efficiency of CAC. At the same concentration (20 mg/L), the removal efficiency of CAC is higher than that of FWAC. This suggests that at 30 mg/L, a similar trend should occur. Experiments at 10 and 30 mg/L using CAC should be performed to confirm this trend.

10 mg of adsorbent is not enough to bring the phenol concentration below the permissible limit of phenol in wastewater (0.1 mg/L). Using FWAC, the final concentrations are 4.49, 10.58, and 1.44 mg/L for initial concentrations of 10, 20, and 30 mg/L, respectively. Using CAC, the final concentration is 2.76 mg/L. The amount of adsorbent should be varied to determine how much adsorbent is needed to bring the concentration below 0.1 mg/L.

8.2.2 Kinetics of phenol adsorption

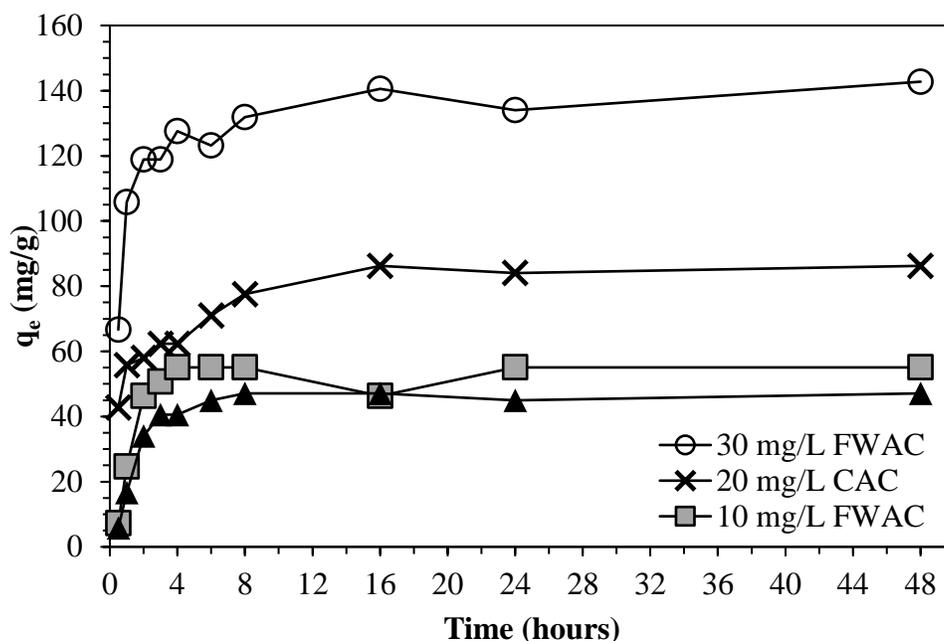


Figure 3. Amount of phenol adsorbed at equilibrium (q_e) as a function of time (hours) at various initial phenol concentrations (10, 20, 30 mg/L) on FWAC and CAC.

As shown in **Figure 3**, rapid adsorption occurs during the first 2 hours. Over time, the adsorption rate plateaus, indicating that equilibrium was achieved. This makes sense since there are more available sites in the first stages of adsorption. At equilibrium, the amount of phenol adsorbed (q_e) increases with increasing initial concentration. At initial concentrations of 10, 20, and 30 mg/L, q_e on FWAC are 27.5, 47.1, and 142.7 mg/g, respectively.

As described in the previous section, CAC is expected to have a higher adsorption capacity than FWAC. Comparing FWAC and CAC at 20 mg/L, the results show a similar trend; q_e on CAC (86.2 mg/g) is about two times greater than q_e on FWAC.

Furthermore, the results show that higher initial concentrations require longer equilibrium times. Phenol solutions with initial concentrations of 10 mg/L and 20 mg/L reach equilibrium at around 5 hours. However, when the concentration is increased to 30 mg/L, equilibrium is reached after around 16 hours.

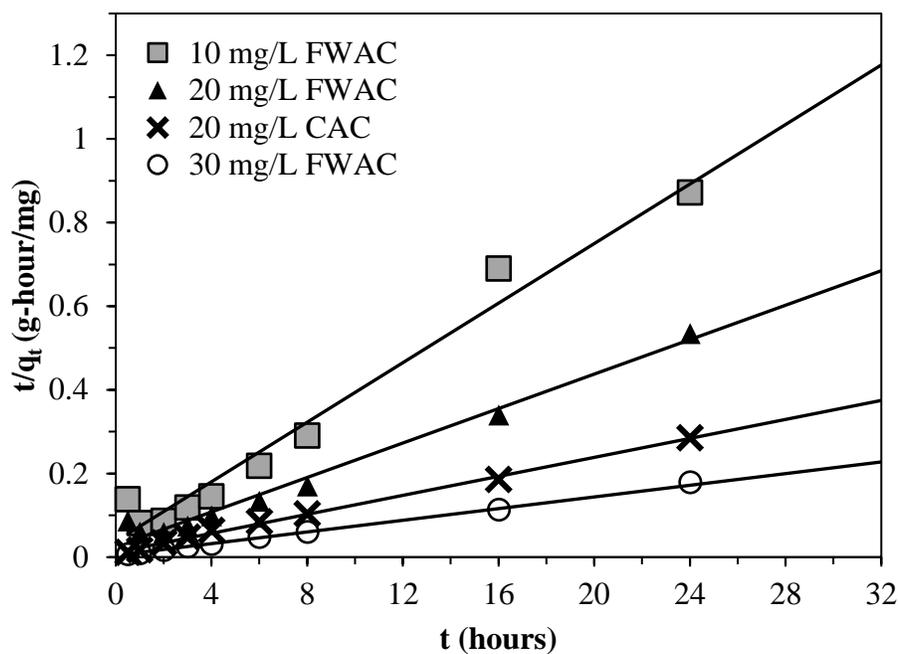


Figure 4. Pseudo-second order plot of phenol adsorption on FWAC and CAC.

Table 1. Kinetic parameters for phenol adsorption on FWAC and CAC at various concentrations.

| C_0 (mg/L) | FWAC | | | CAC |
|---------------------------------|-------|-------|--------|-------|
| | 10 | 20 | 30 | 20 |
| $q_{e,exp}$ (mg/g) | 27.54 | 47.10 | 142.75 | 86.23 |
| Pseudo-first order | | | | |
| $q_{e,cal}$ (mg/g) | 8.96 | 15.05 | 32.94 | 28.41 |
| k_1 (hr^{-1}) | 0.060 | 0.480 | 0.906 | 0.567 |
| R^2 | 0.156 | 0.480 | 0.567 | 0.906 |
| Pseudo-second order | | | | |
| $q_{e,cal}$ (mg/g) | 28.09 | 48.54 | 142.86 | 87.72 |
| h_0 (mg/g/hr) | 0.038 | 0.026 | 0.004 | 0.012 |
| k_2 (g/mg/hr) | 0.034 | 0.017 | 0.011 | 0.011 |
| R^2 | 0.993 | 0.995 | 0.999 | 0.995 |
| Intraparticle diffusion | | | | |
| I | 15.99 | 23.26 | 98.10 | 49.94 |
| k_3 (mg/g/hr ^{1/2}) | 2.34 | 4.87 | 8.20 | 6.68 |
| R^2 | 0.316 | 0.440 | 0.526 | 0.778 |

After fitting the data in **Figure 3** to kinetic models, it was found that phenol adsorption on FWAC is best described by pseudo-second order. This plot is shown above in **Figure 4**. The correlation coefficients R^2 for pseudo-second order are much higher than those for pseudo-first order (**Table 1**). Also, the pseudo-second order model calculated q_e values similar to the experimental values ($q_{e,exp}$). For example, the amount of phenol adsorbed at 10 mg/L on FWAC was experimentally determined to be 27.54 mg/g, while the pseudo-second order model calculated it to be 28.09 mg/g. In contrast, the pseudo-first order model calculated it to be 8.96 mg/g, which is much lower than $q_{e,exp}$. For these reasons, pseudo-second order is the best fit. This result is consistent with the kinetics behavior of other activated carbon samples (Mishra S. et al., 2019; Jeong et al., 2020; Xie et al., 2020).

Because the data best fits the pseudo-second order model, this means that the rate of phenol adsorption is controlled by chemisorption. In other words, phenol adsorbs to the surface of activated carbon by chemical bonding and creates a monolayer. This can explain why phenol adsorption decreases when contact time and initial concentration increase. As shown by **Table 1**, the initial adsorption rate h_0 on FWAC decreases as the initial concentration increases. This was also observed earlier; it was determined that equilibrium times are longer at higher initial concentrations. Because the process follows chemisorption, adsorption rate decreases due to the limited number of sites.

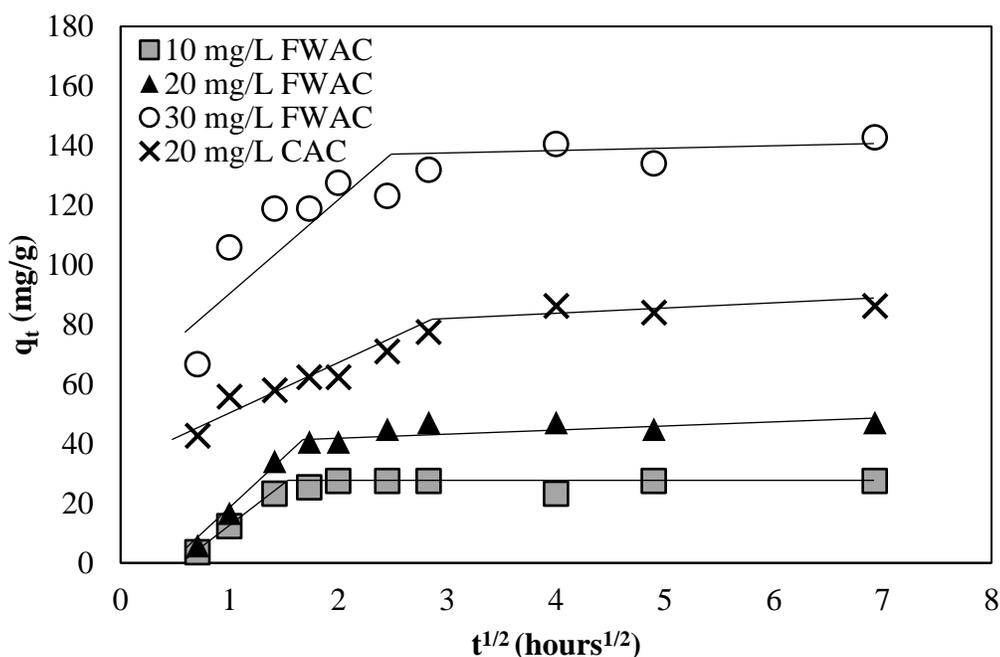


Figure 5. Adsorption data fitted to intraparticle diffusion model.

As shown by **Table 1** and **Figure 5**, the data does not fit a line passing through the origin, but fits multiple lines. R^2 ranges from 0.316 to 0.778, further demonstrating that the fit is not linear. This means that intraparticle diffusion is not the only process controlling the rate of phenol adsorption on FWAC and CAC. It is also controlled by surface adsorption, as indicated by the

intercepts. The intercepts increase from 15.99 to 98.10 as the initial concentration increases from 10 mg/L to 30 mg/L (**Table 1**). This means that the boundary layer effect increases and further explains why phenol removal efficiency decreases when initial concentration increases. These results agree with the diffusion kinetics of other activated carbon samples (Mishra S. et al., 2019; Xie et al., 2020).

8.2.3 Isotherm of phenol adsorption on FWAC

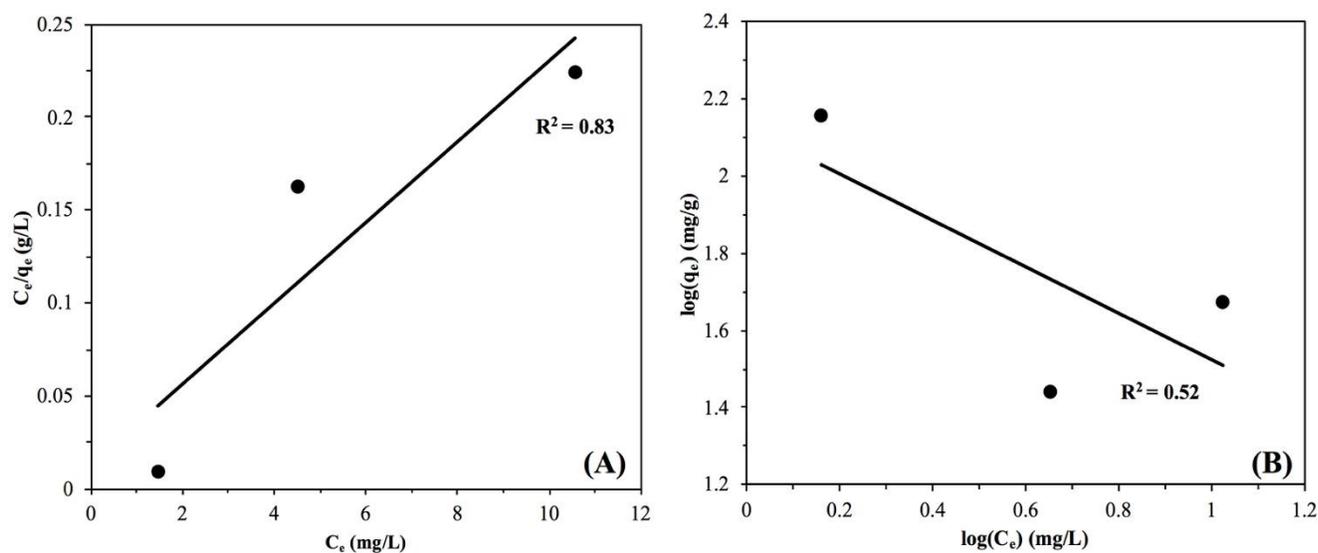


Figure 6. (A) Adsorption data fitted to Langmuir and (B) Freundlich adsorption isotherm models.

The data best fits the Langmuir isotherm model, meaning that phenol forms a monolayer during adsorption and the solutions reach equilibrium. This result agrees with the process' pseudo-second order kinetic behavior. As shown in **Figure 6**, R^2 for the Langmuir isotherm is higher than that for Freundlich isotherm. Other studies on biomass-derived activated carbons have values of R^2 ranging from 0.97–0.99, so more initial concentrations should be tested to increase the fit of the data. However, the results are still consistent with other studies, as many researchers have shown that phenol adsorption on activated carbons follows the Langmuir isotherm (Xie et al., 2019; Doke and Khan, 2017).

Table 2 summarizes the Langmuir and Freundlich parameters. The separation factor R_L shows that adsorption is favorable at 10 mg/L, 20 mg/L, and 30 mg/L since $0 < R_L < 1$. Adsorption is the most favorable at 30 mg/L since there is more phenol molecules than adsorption sites at this concentration. Furthermore, the maximum adsorption capacity (q_m , mg/g) of FWAC was calculated to be 46.30 mg/g. This is comparable to other activated carbons derived from food waste i.e. corn husks, sugar cane, coconut shells, and date pits and even performs better than many of them (**Table 2**). Compared to commercial activated carbons, q_m of FWAC is within the adsorption capacity range of 30.2187 and 176.58 mg/g, suggesting that FWAC are a viable alternative to commercial activated carbons. However, more experiments need to be performed to determine q_m for CAC. q_m of other commercial ACs varied greatly depending on where they were manufactured e.g. granular AC.

Table 2. Isotherm parameters for phenol adsorption on FWAC.

| Langmuir | |
|-------------------|--------|
| q_m (mg/g) | 46.30 |
| K_L (L/mg) | 1.56 |
| R_L 10 mg/L | 0.06 |
| 20 mg/L | 0.03 |
| 30 mg/L | 0.02 |
| R^2 | 0.83 |
| Freundlich | |
| K_F (mg/g) | 133.78 |
| n | -1.65 |
| R^2 | 0.52 |

Table 3. Comparison of maximum adsorption capacities of various activated carbons for phenol.

| Adsorbent | q_m (mg/g) | Reference |
|--|--------------------------------|---------------------------|
| FWAC | 46.30 | This work |
| Corn husk AC (CHAC ₈₀₀) | 8.445 | (Mishra S. et al., 2019) |
| Sugar cane bagasse fly ash | 23.832 | (Srivastava et al., 2006) |
| Coconut shells AC | 49.87 | (Singh et al., 2008) |
| Date pits AC | 46.076 | (Banat et al., 2004) |
| CAC | --- | This work |
| Commercial AC (from Rajasthan Breweries) | 30.2187 | (Srivastava et al., 2006) |
| Commercial granular AC (from LOBA Chemie) | 74.12 | (Vasu et al., 2008) |
| Commercial granular AC (GAC ₉₅₀ , from Sichuan Nan-Ke Activated Carbon) | 169.91 | (Xie et al., 2020) |
| Commercial powdered granular AC (PAC ₈₀₀ , from Sichuan Nan-Ke Activated Carbon) | 176.58 | (Xie et al., 2020) |

9 Conclusion and Recommendations

In this work, the adsorption of phenol on FWAC and CAC were studied and compared. The results show that phenol adsorption on FWAC is optimal at pH 8.63 since leaching and electrostatic interactions are minimal. Removal efficiency on FWAC also decreases as initial concentration increases, but additional experiments should be performed to confirm this result. The amount of adsorbent should also be varied to determine how much adsorbent is needed to bring the concentration below 0.1 mg/L since 10 mg was insufficient. Furthermore, the mechanism of phenol adsorption is chemisorption or monolayer formation, as the data best fits the pseudo-second order kinetic model and Langmuir isotherm model. The process is controlled by both intraparticle diffusion and surface adsorption, as shown by the multi-linear fit of the intra-particle diffusion model. Lastly, the maximum adsorption capacity of FWAC was calculated to be 46.30 mg/g by the Langmuir model. Compared to values in literature, the value for FWAC falls within the range for commercial activated carbons and performs better than many other food waste-derived carbons. However, adsorption experiments on CAC should be completed to further support this result.

10 References

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