

ADSORPTION OF PHENOL FROM AQUEOUS SOLUTION BY MAIZE TASSELS

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Abstract

The adsorption of phenol which is one of the most important organic pollutant was studied. The effect of contact time, adsorbent dosage and temperature on the adsorption capacity was investigated. The maximum phenol adsorption was obtained as 54% at a temperature of 75°C and at a pH of 6. Freundlich and Langmuir adsorption models were used for mathematical description of the adsorption equilibrium. The experimental data fitted well into the Langmuir isotherm.

Key Words: Phenol , adsorption, Langmuir isotherm, Freundlich Isotherm

INTRODUCTION

Phenols are generally considered to be one of the important organic pollutants discharged into the environment causing unpleasant taste and odour of drinking water (Dursan et al, 2005). Phenols are pollutants of high priority concern because of their toxicity and possible accumulation in the environment. They are introduced into surface water from industrial effluents such as those from pharmaceutical, steel, industries, domestic wastewaters, wastewaters from paints, pesticide, coal conversion, resin, petroleum and petrochemical industries and agricultural run-off. Traditionally, biological treatment, reverse osmosis, coagulation, sedimentation, ion exchange and solvent extraction are the most widely used techniques for removing phenols and related organic substances. Activated carbon from coal is widely used for

28 the removal of a variety of organics from water but the disadvantage associated
29 with it is the high regeneration cost and the generation of carbon fines due to
30 the brittle nature of carbons used for the removal of organic species (Arellano-
31 Cardenas et al, 2005). Research interests into the production of alternative
32 adsorbents to replace the costly activated carbon have intensified and have led to
33 more effective and economic natural materials such as those of agricultural origin
34 because of their low cost and local availability (Lin and Juang, 2008). Activated
35 carbons starting from agricultural low-value by products have the advantage of
36 exhibiting a high adsorption capacity for organic pollutants due to their high
37 surface area or porous structure (Dursan et al, 2005). The application of agricultural
38 materials in wastewater treatment has been reported (Doyurum and Celik, 2006;
39 Kumar, 2006; Lakatos et al., 2002; Mohan and Pittman, 2006; Namasiyayam and
40 Yamuna, 1995). From the more than hundred agricultural materials reported, no
41 studies have been carried out on use of maize tassels to remove phenol. Zvinowanda
42 and coworkers (Zvinowanda et al., 2008a, b; 2009a, b) found maize tassels to have
43 immense potential as an alternative adsorbent for toxic metal ion remediation in
44 polluted water and wastewater. Maize tassels are found in large quantities from maize
45 producing countries such as South Africa, Mexico, Brazil, China, Indonesia, Argentina
46 and USA. Many studies have been conducted on the adsorption of phenol using
47 synthetic resins and low cost adsorbents such as coal, red mud, bagasse fly ash, coal
48 fly ash, sewage sludge, clay and many other materials. The adsorption capacities
49 obtained for some of these materials are red mud-59.2mg/g, bagasse fly ash-23.8mg/g,
50 coal fly ash-17.9mg/g, rice husk-4.5mg/g and coal-18.1mg/g. Most of these materials

have shown good adsorption characteristics however, there has been much done on obtaining a comparative overview on removal performance, adsorption capacity and cost effectiveness. (Lin and Juang, 2008). Another study was performed using activated carbon synthesized from pecan shells through the modification with sodium dodecyl sulphate surfactant and the results obtained showed moderate adsorption for phenol with a low adsorption capacity of 18mg/g at pH 11. (Shawabkeh and Abu-Nameh, 2005)

MATERIALS AND METHOD

PREPARATION OF MAIZE TASSELS

The maize tassels were collected from a local farm in Bindura, Mashonaland Central Province and they were placed in polythene bags. The maize tassels were first cut into small pieces about 10cm and washed to remove dust particles. Then they were dried in an oven at 105°C for 24 hours. The tassels were then ground and sieved to 75 mesh size to separate the materials into discrete particle size ranges (Dursan et al, 2005). Then 25g of the powder was placed in a muffle furnace at 400°C for 1 hour and later allowed to cool to room temperature. The carbon was then stored in a closed bottle (Zvinowanda et al, 2009). buffer 10.

PREPARATION OF STOCK SOLUTION

The stock solution was prepared by dissolving 1.0030 g of phenol in 1dm³ of distilled water. The test solutions were prepared by diluting the stock solution to the desired concentrations. The concentration range varied from 25-500mg/dm³.

72 **ADSORPTION STUDIES**

73 Phenol adsorption was performed at various initial concentrations and temperatures at
74 constant 150rpm shaking glass flasks of 0.25dm³ containing 0.1dm³ phenol solution at
75 desired concentration including 0.05g of maize tassel carbon using a shaker. 5cm³
76 samples were taken before mixing the carbon and phenol and during mixing at 30
77 minutes intervals for determining the residual phenol concentration in the medium.
78 Before analysis the samples were filtered by using Whatman filter paper and the
79 supernatant fluid was analyzed for the remaining phenol.

80 **EFFECT OF pH**

81 The effect of pH on adsorption was investigated in the pH range 2-10 at 25°C. The pH of
82 solution was adjusted to the desired value by adding a few drops of 1N HCl or 1N NaOH
83 solutions to the initial solution.

84 **EFFECT OF ADSORBENT DOSAGE**

85 Adsorption dose experiments were performed with 100ml of 150mg/L phenol solution
86 with the following adsorbent masses 0.4, 0.8, 1.2, 1.6 and 2.0g at 25°C. The pH of the
87 solution was adjusted to optimum pH of 6. After 1 hour the suspension was filtered and
88 the filtrate analyzed for unabsorbed phenol.

89 **EFFECT OF CONTACT TIME**

90 Experiments for the effect of time were performed following the same procedure as
91 described earlier, but an optimum pH for phenol, fixed temperature (25±2°C), fixed
92 concentration (150mg/L) and adsorbent dose (1.0g/100ml). Six sets of samples were

prepared in triplicate and placed in a water bath with a shaker set at 150rpm. After every 30 minutes, three samples were removed and filtered immediately and the filtrate analyzed for residual phenol.

EFFECT OF SOLUTION TEMPERATURE

Experiments for the reaction temperature were also performed following the same procedure with all other parameters fixed, but at different temperature range 25, 50, 75, 100 and 125°C.

ANALYSIS

The concentration of initial and residual phenol in the adsorption media was determined spectrophotometrically at an absorbance of 270nm (Srirastava et al, 2006; Kumar and Min, 2011).

RESULTS

The equation (1) below was used to calculate Q_e

$$Q_e = \left(\frac{C_0 - C_e}{m} \right) V \quad (1)$$

Where Q_e – equilibrium amount of adsorbate

C_0 - initial concentration of adsorbate

C_e – equilibrium concentration of adsorbate

110 V – volume used

111 M – mass of adsorbent

112 The percentage removal for phenol was calculated using the equation (2) below :

113 % Adsorption capacity = $[(C_o - C_e) / C_o] \times 100$ (2)

114 **Table 1: The effect of adsorbent dosage**

Adsorbent dosage(mg)	Co(mg/L)	Ce(mg/L)	Qe(mg/g)	Ce/Qe(g/L)	Adsorption capacity/%
0.4	150	74.9	3.8	19.7	50.1
0.8	150	73.2	4.8	15.25	51.2
1.2	150	71.9	6.5	11.1	52.1
1.6	150	70.7	9.9	7.1	52.9
2.0	150	68.8	20.3	3.4	54.1

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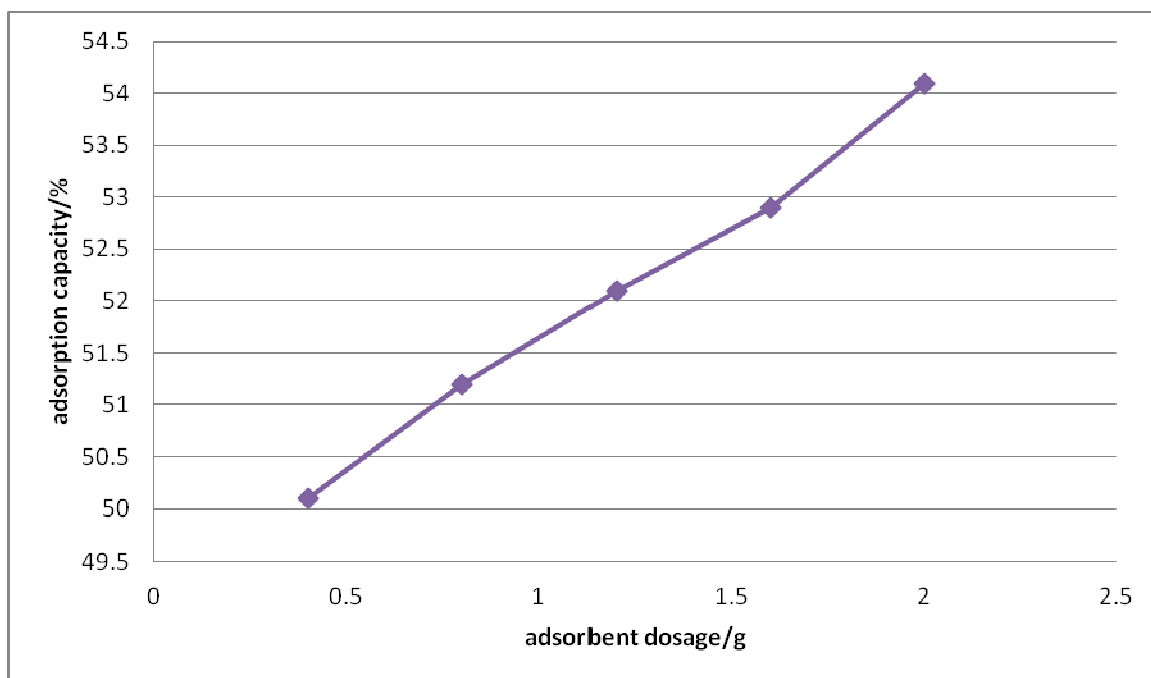


Fig 1: Graph of adsorbent dosage against absorption capacity

Table II: The effect of contact time

Contact time	C_0 (mg/L)	C_e (mg/L)	Q_e (mg/g)	C_e/Q_e (g/L)	Adsorption capacity/%
30	150	72.6	7.74	9.38	51.6
60	150	72.4	7.76	9.33	51.7
90	150	71.9	7.81	9.21	52.1
120	150	69.7	8.03	8.68	53.5
150	150	71.9	7.81	9.21	52.1
180	150	72.4	7.76	9.33	51.7

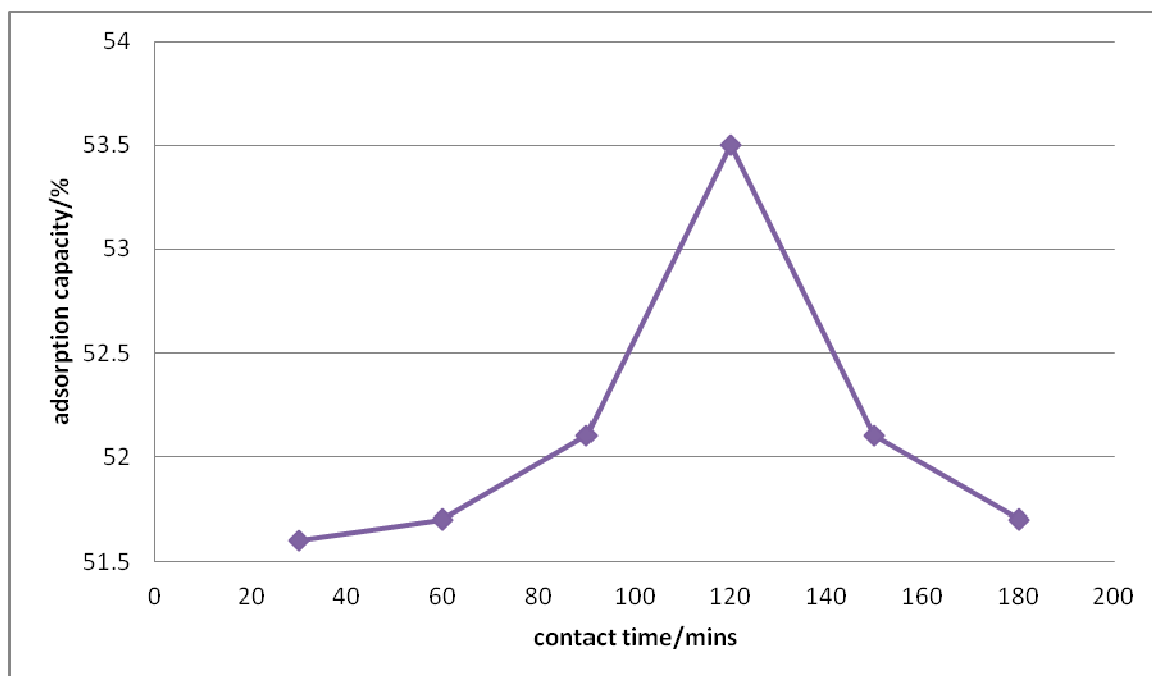


Figure 2: Graph of contact time against adsorption capacity

Table III: The effect of pH

pH	C_o (mg/L)	C_e (mg/L)	Q_e (mg/g)	C_e/Q_e (g/L)	Adsorption capacity/%
2	150	77.0	7.3	10.55	48.5
4	150	76.5	7.35	10.41	49.0
6	150	74.3	7.57	9.82	50.5
8	150	83.1	6.69	12.42	44.6
10	150	91.4	5.86	15.60	39.1

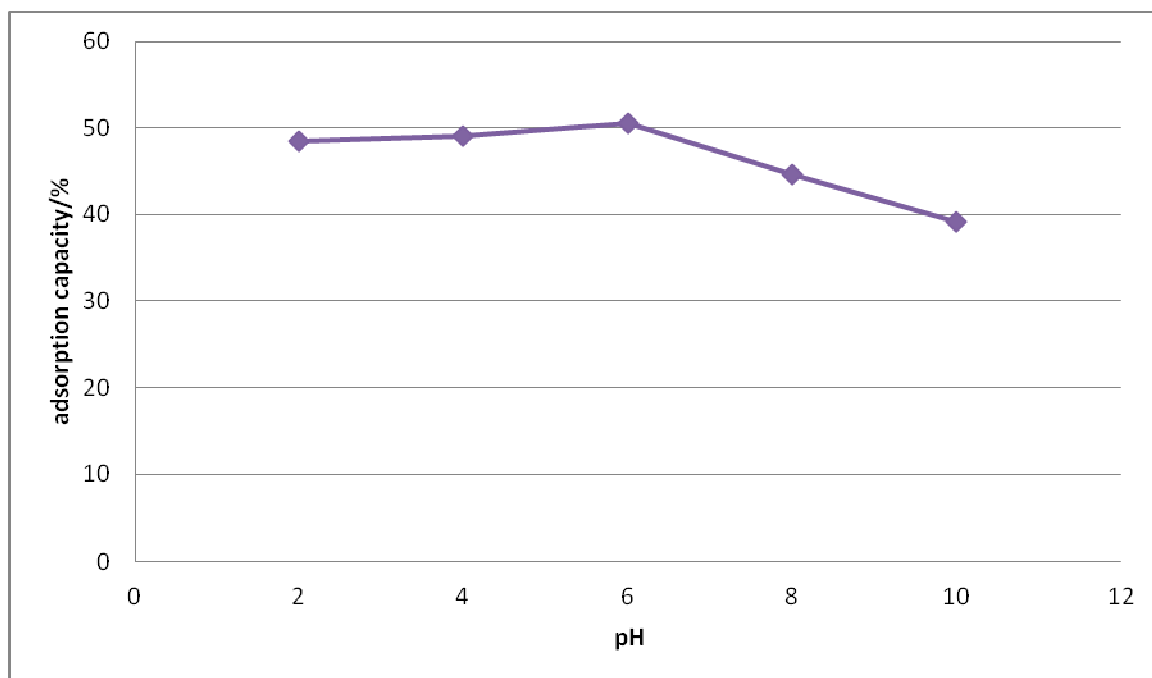


Figure 3: Graph for the effect of pH against adsorption capacity

Table IV: The effect of temperature

Temperature	C_0 (mg/L)	C_e (mg/L)	Q_e (mg/g)	C_e/Q_e (g/L)	Adsorption capacity/%
25	150	73.2	7.68	9.53	51.2
50	150	72.6	7.74	9.38	51.6
75	150	71.8	7.82	9.18	52.1
100	150	73.5	7.65	9.61	51.0
150	150	74.5	7.55	9.87	50.3

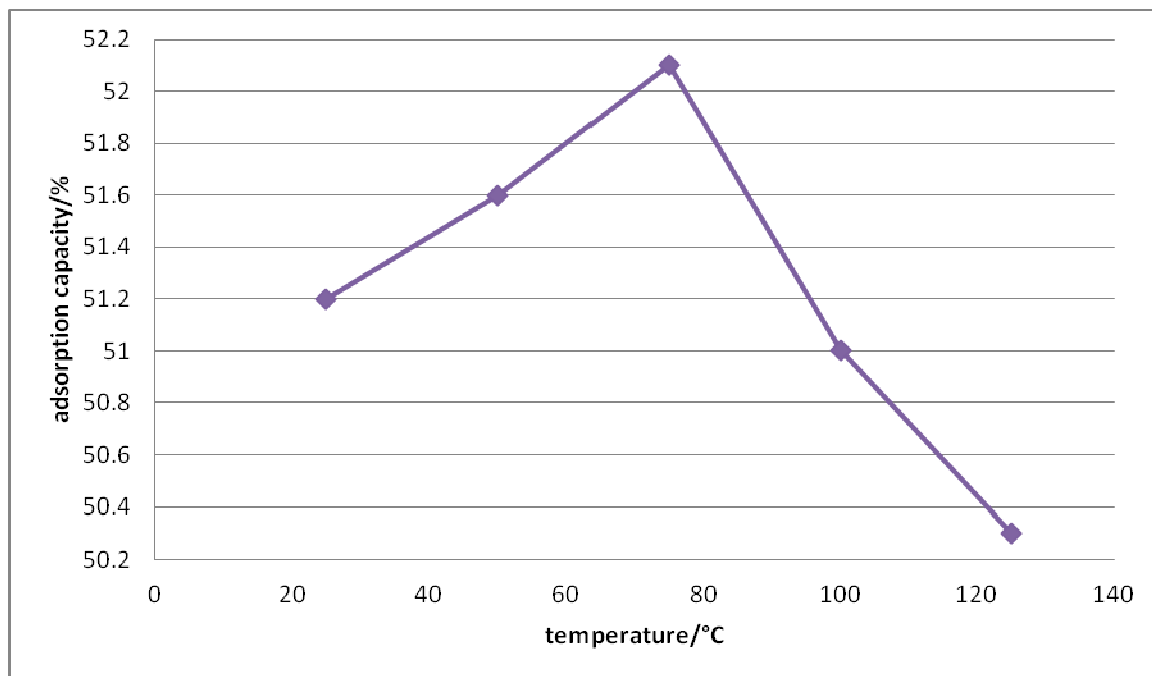


Figure 4: Graph for the effect of temperature against adsorption capacity

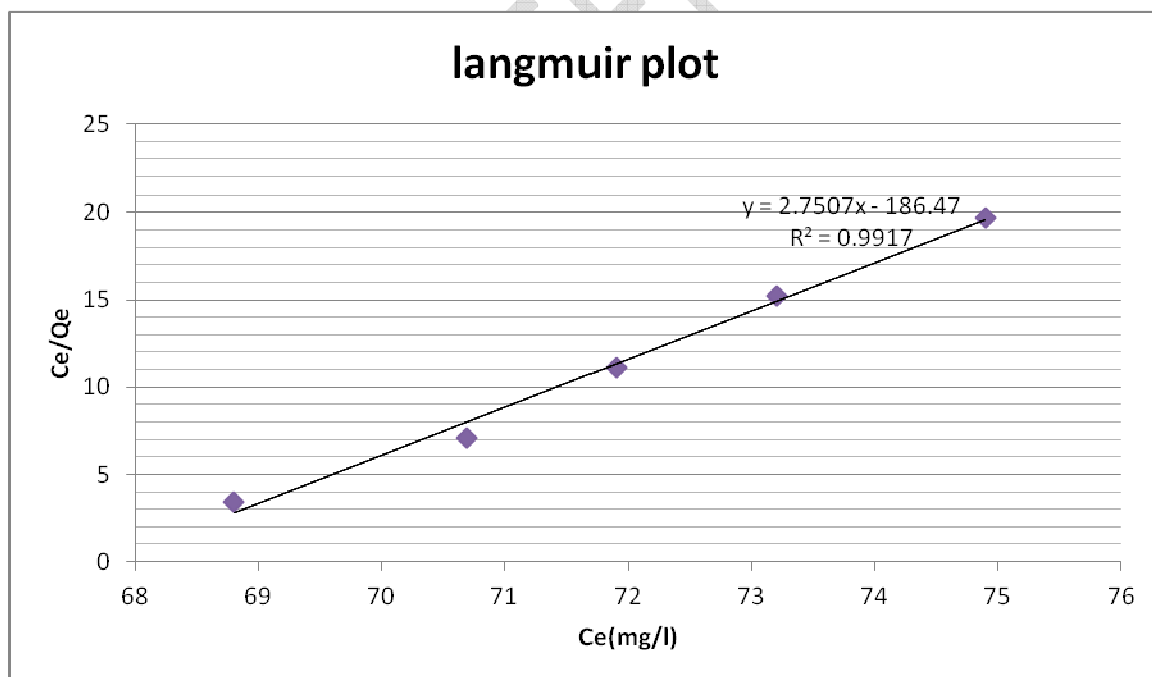


Figure 5: Langmuir adsorption isotherm for the effect of adsorbent dosage

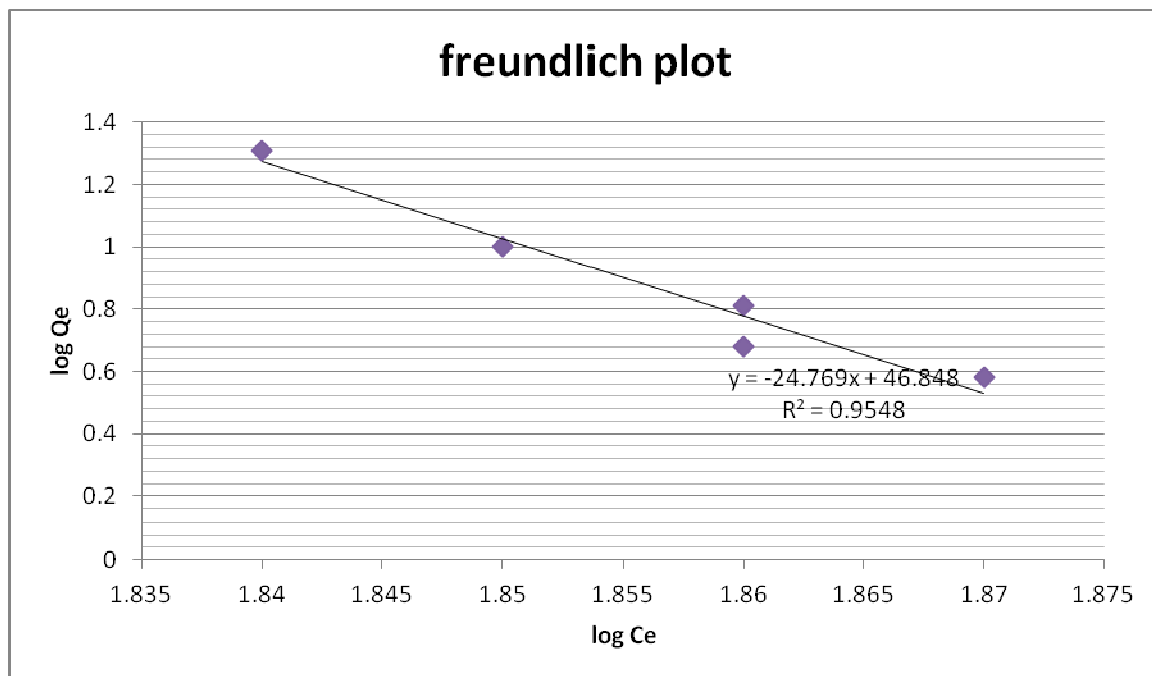


Figure 6: Freundlich adsorption isotherm for the effect of adsorbent dosage

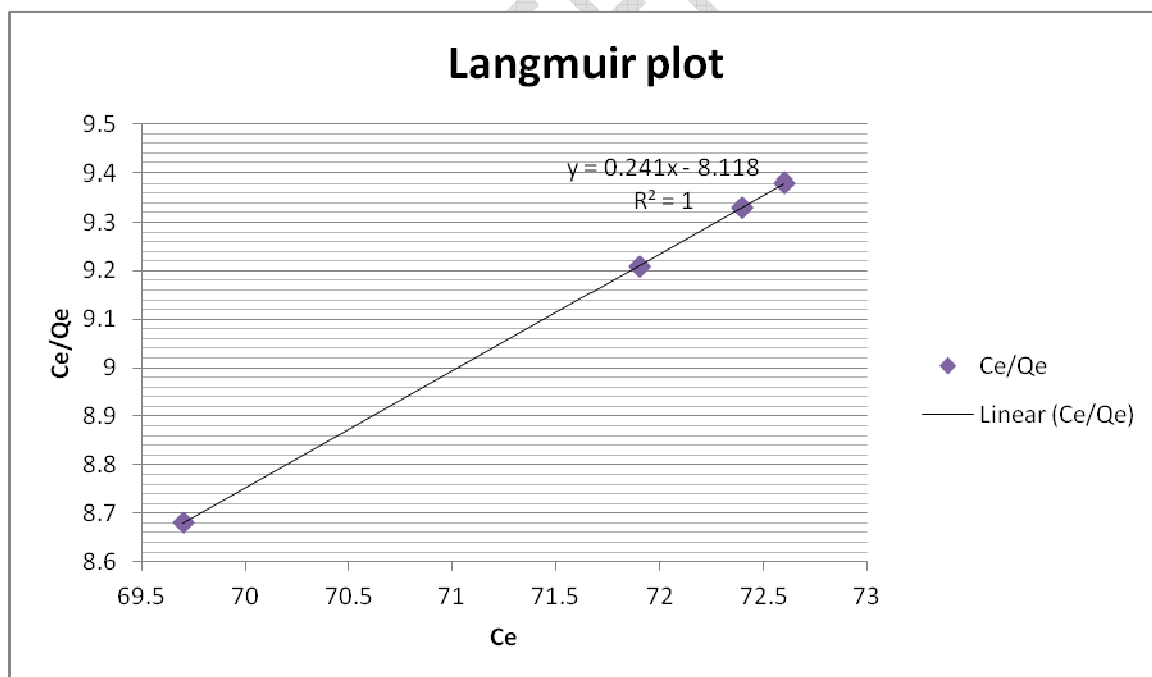


Figure 7: Langmuir adsorption isotherm for the effect of contact time

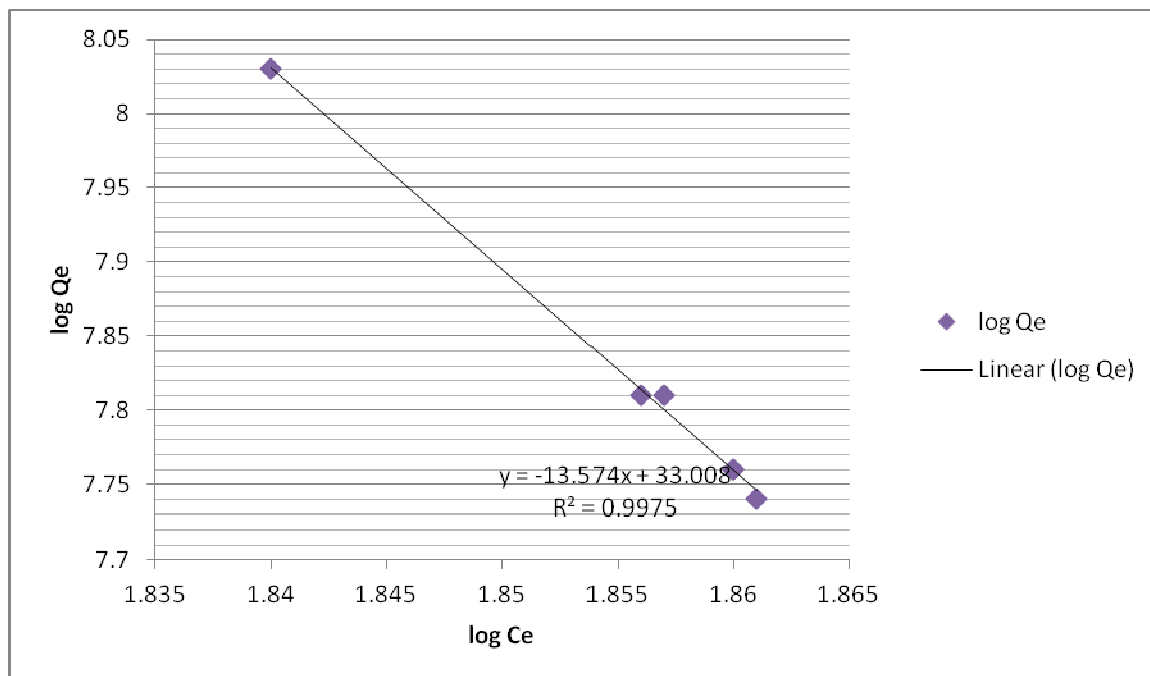


Figure.8: Freundlich adsorption isotherm for the effect of contact time

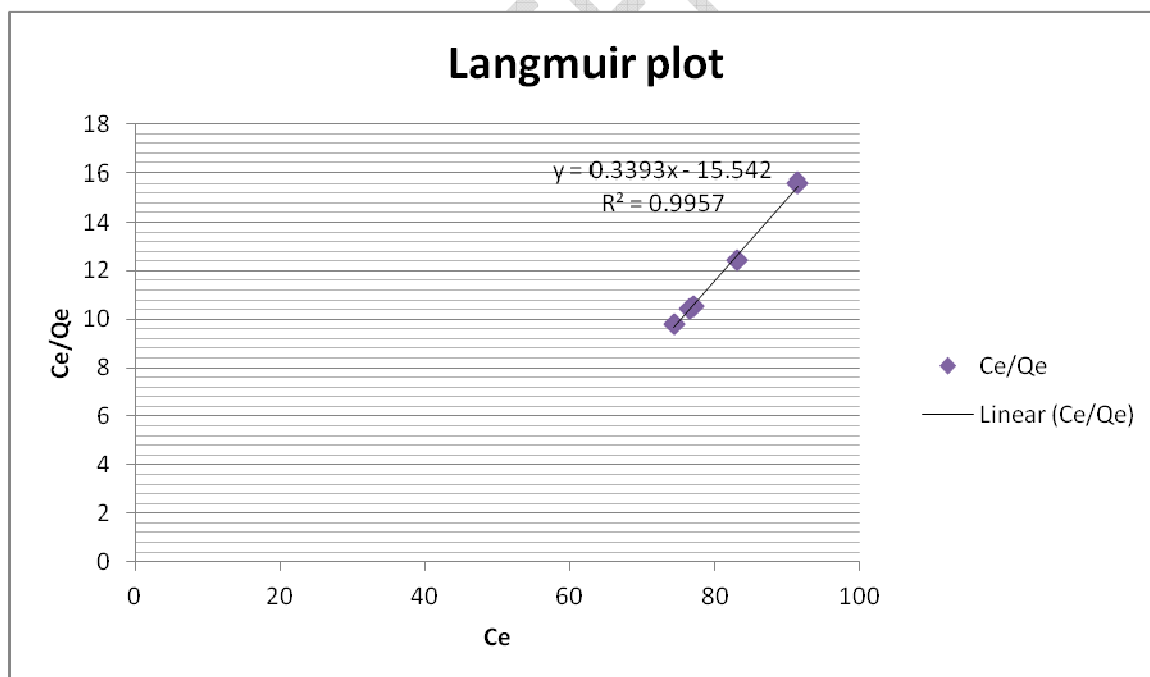


Figure 9: Langmuir adsorption isotherm for the effect of pH

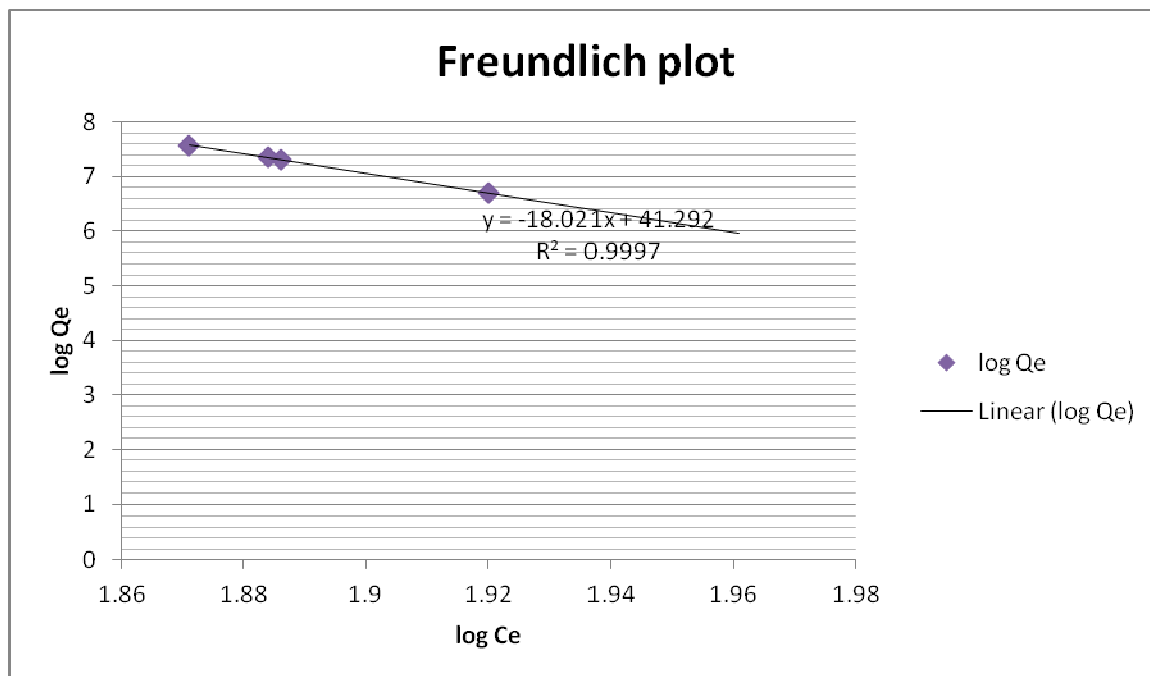


Figure 10: Freundlich adsorption isotherm for the effect of pH

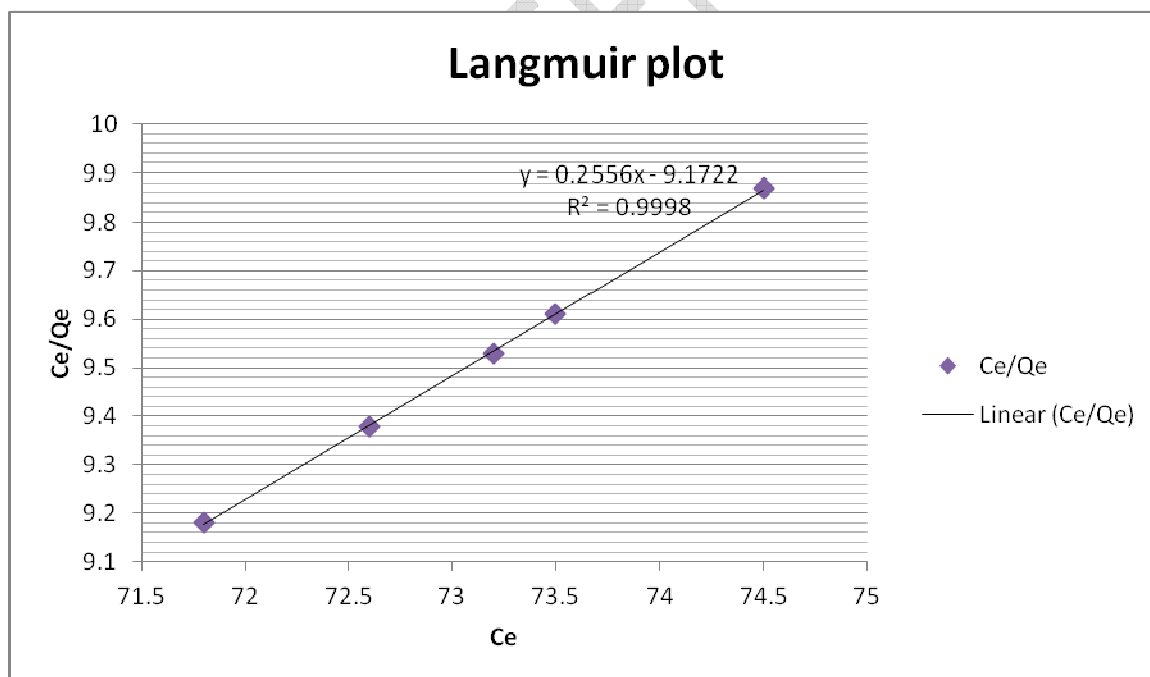


Figure 11: Langmuir adsorption isotherm for the effect of temperature

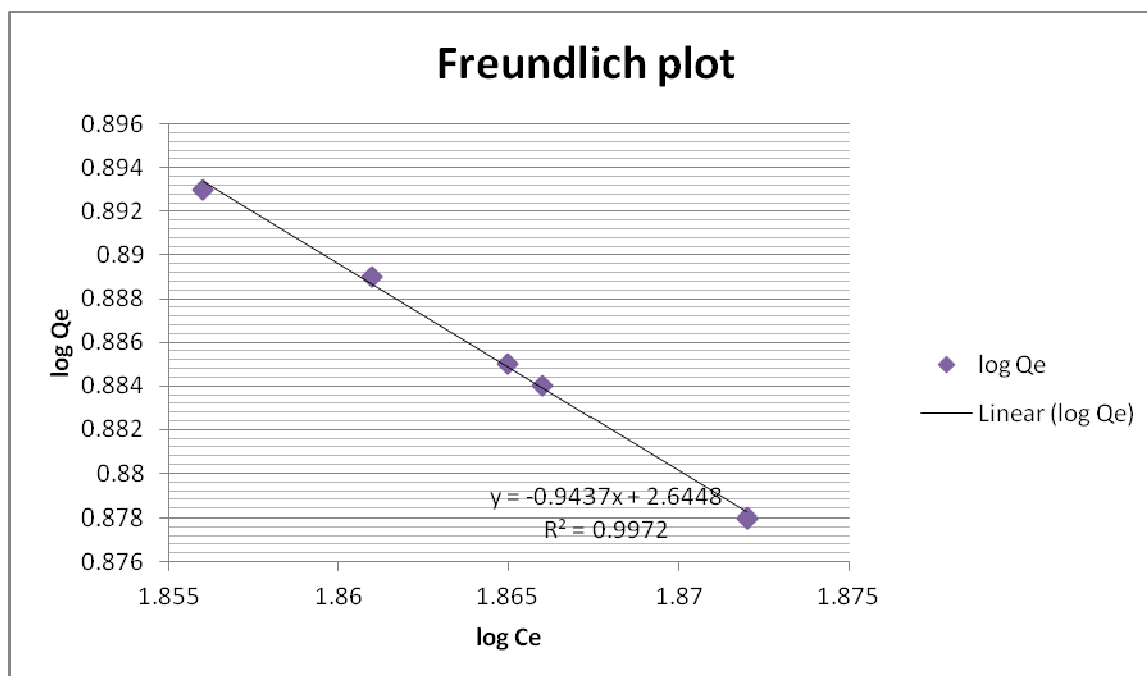


Figure 12: Freundlich adsorption isotherm for the effect of temperature

DISCUSSION

EFFECT OF pH

The effect of pH was investigated from pH 2-10 and the results obtained showed that as the pH increased the adsorption also increased up to pH 6, then from there the adsorption decreased as pH increased as shown by Figure 1. According to Horsfall (2004) adsorption is a pH dependent process and pH dependent binding suggests that phenol is adsorbed by the adsorbent through carboxyl, carbonyl or hydroxyl ligands. The decrease in phenol adsorption from pH = 6 to 2 was due to the increased H^+ adsorption on the carbonyl sites, which suppresses phenol adsorption on these sites. On the other hand, the decrease in the phenol amount adsorbed from pH = 6 to 10 was probably attributed to both

greater solubility of dissociated phenol at $\text{pH} > \text{pK}_a$ and increased repulsion forces between the dissociated form of the adsorbate and the carbon surface. Mattson et al (1969) indicated that phenol and its derivatives adsorb on activated carbon via a donor-acceptor complex mechanism that involves carbonyl surface-oxygen groups acting as electron donor and the aromatic ring of the solute acting as an acceptor.

EFFECT OF ADSORBENT DOSAGE

The effect of adsorbent dosage was investigated using adsorbent dosages which ranged from 0.4 to 2.0g. This was investigated at the optimum pH 6 and the results showed that as the adsorbent dosage increased the adsorption capacity also increased. The more the adsorbent dosage meant more adsorption sites therefore more phenol was adsorbed. The maximum adsorption capacity was observed for the 2g adsorbent dosage as shown by Figure 1. According to a study by Srirastava et al (2006) the removal of phenol increased with increase in adsorbent dosage.

EFFECT OF CONTACT TIME

The effect of contact time was investigated at pH 6 and an adsorbent dosage of 1.0g. It was noted that as the contact time increased adsorption capacity also increased meaning more phenol was adsorbed with an increase in contact time, this might have been due to the increased number of vacant sites on the adsorbent. However there was a decrease as the contact time increased this might have been caused by the fact that all the adsorbent sites were already occupied. The maximum adsorption capacity was

seen after 120 minutes. Similar trends were also observed in other investigations (Uddin et al, 2007).

EFFECT OF TEMPERATURE

This was investigated at a pH of 6, an adsorbent dosage of 1.0g and contact time was set at 1 hour. At the beginning adsorption capacity increased with the increase in temperature as shown by the graph in Figure 4. The adsorption decreases with increasing temperature because theoretically the process of physisorption takes place at low temperature and decreases with increasing temperature. The maximum adsorption capacity was observed at 75°C. A similar trend was also observed by Horsfall and Spiff (2005).

CONCLUSION

The carbon from maize tassels has great potential as an adsorbent. Maximum adsorption took place at optimum pH of 6, adsorbent dosage of 2g and at a temperature of 75°C and contact time of 120 minutes. The adsorbent was required in large amounts for the process to attain equilibrium faster. Generally the removal of phenol required lower temperatures. The data fitted well into the Langmuir adsorption isotherm and not the Freundlich adsorption isotherm. The Langmuir model assumes that adsorption takes place at specific homogeneous sites on the surface of the adsorbent and also, when a site is occupied by an adsorbate molecule, no further adsorption can take place at this site.

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UNDER PEER REVIEW