

ADSORPTION OF PHENOL FROM AQUEOUS SOLUTION USING CARBONIZED MAIZE TASSELS

Netai muchanyereyi^{1*}, Lydia Chiripayi², David Shasha³, Mathew Mupa⁴

^{1,2,3,4}Bindura university of Science Education, P.Bag 1020, Bindura,Zimbabwe

ABSTRACT

The adsorption of phenol which is one of the most important organic pollutant was studied using carbon from maize tassels. 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 75⁰C 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.

Keywords: Phenol , adsorption, maize tassel carbon Langmuir isotherm, Freundlich Isotherm

1. INTRODUCTION

ADSORPTION OF PHENOL FROM AQUEOUS SOLUTION USING CARBONIZED MAIZE TASSELS

Netai Muchanyereyi, Lydia Chiripayi, David Shasha, M.Mupa

Abstract

The adsorption of phenol which is one of the most important organic pollutant was studied using carbon from maize tassels. 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 75⁰C 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, maize tassel carbon 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 [1]. 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,

* Tel.: + 263 0773 410 239.

E-mail address: nmuchanyereyi@gmail.com.

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 the removal of a variety of organics from water but the disadvantage associated with it is the high regeneration cost and the generation of carbon fines due to the brittle nature of carbons used for the removal of organic species [2]. Research interests into the production of alternative adsorbents to replace the costly activated carbon have intensified and have led to more effective and economic natural materials such as those of agricultural origin because of their low cost and local availability [3]. Activated carbons starting from agricultural low-value by products have the advantage of exhibiting a high adsorption capacity for organic pollutants due to their high surface area or porous structure [1]. The application of agricultural materials in wastewater treatment has been reported [4],[5],[6],[7],[8]. From the more than hundred agricultural materials reported, no studies have been carried out on use of maize tassels to remove phenol. Zvinowanda and coworkers,[9],[10] found maize tassels to have immense potential as an alternative adsorbent for toxic metal ion remediation in polluted water and wastewater. Maize tassels are found in large quantities from maize producing countries such as South Africa, Mexico, Brazil, China, Indonesia, Argentina and USA. Many studies have been conducted on the adsorption of phenol using synthetic resins and low cost adsorbents such as coal, red mud, bagasse fly ash, coal fly ash, sewage sludge, clay and many other materials. The adsorption capacities obtained for some of these materials are red mud-59.2mg/g, bagasse fly ash-23.8mg/g, 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.[3]. 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. [11]. In this study carbon from maize tassels was used to remove phenol from aqueous solution. To the best of our knowledge this has not been reported in literature

2. MATERIAL AND METHODS

2.1 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 [1]. 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 [9], buffer 10.

2.2 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.

2.3 ADSORPTION STUDIES

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

98 **2.4 EFFECT OF pH**

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

102 **2.5 EFFECT OF ADSORBENT DOSAGE**

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

107 **2.6 EFFECT OF CONTACT TIME**

108 Experiments for the effect of time were performed following the same procedure as
109 described earlier, but an optimum pH for phenol, fixed temperature (25±2°C), fixed
110 concentration (150mg/L) and adsorbent dose (1.0g/100ml). Six sets of samples were
111 prepared in triplicate and placed in a water bath with a shaker set at 150rpm. After every 30
112 minutes, three samples were removed and filtered immediately and the filtrate analyzed for
113 residual phenol.

114 **2.7 EFFECT OF SOLUTION TEMPERATURE**

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

117 **2.8 ANALYSIS**

118 The concentration of initial and residual phenol in the adsorption media was determined
119 spectrophotometrically at an absorbance of 270nm.[12],

120
121
122
123
124

125 **3. RESULTS AND DISCUSSION**

126

127 The adsorption percentage of phenol was calculated by the difference of initial and final
128 concentration using the equation expressed as follows.

$$\text{Adsorption yield (\%)} = \frac{(C_o - C_t)V}{C_o} \times 100 \quad (1)$$

The adsorption capacity of phenol adsorbed per gram adsorbent (mg/g) was calculated using.

$$q = \frac{(C_o - C_t)V}{W} \quad (2)$$

where C_o and C_t are the initial and at any time (t) concentration (mg/L) of phenol in the solution, V the volume (L) of solution and W is the weight (g) of the adsorbent. For the equilibrium conditions in these equations, C_e (equilibrium concentration) and q_e (adsorbed phenol at equilibrium) must be written instead of C_t and q . C_e and q_e have the same unit with C_t and q , respectively. [

Langmuir isotherm is often used to describe the maximum adsorption capacity of the adsorbent. The Langmuir equation is written as follows.

$$q_e = \frac{q_{\max} K C_e}{1 + K C_e} \quad (3)$$

Equation (3) above can be written in a linear form as follows:

$$\frac{C_e}{q_e} = \frac{1}{K q_{\max}} + \frac{C_e}{q_{\max}}$$

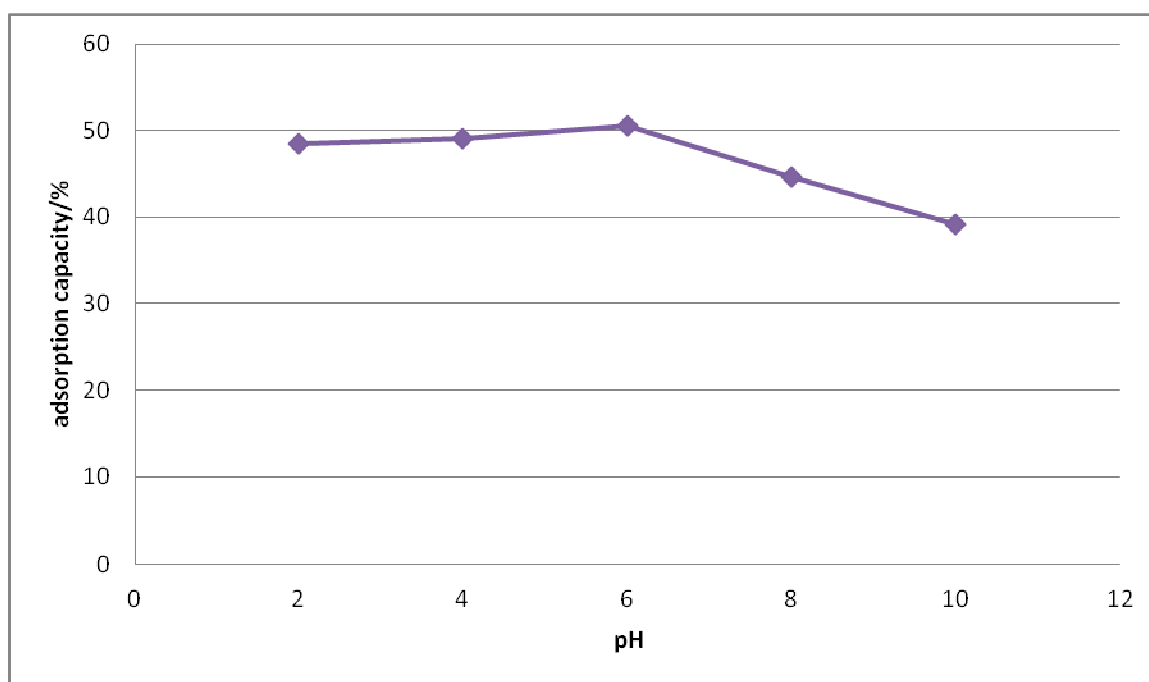
Where $q_{\max}$ and K are Langmuir constants related to maximum adsorption capacity and bonding energy of adsorption. A plot of C_e/q_e versus C_e should be a straight line with a slope $1/q_{\max}$ and intercepts $1/Kq_{\max}$ (as shown in Fig 2)

3.1EFFECT 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 [14], 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 $pH > pK_a$ and increased repulsion forces between the dissociated form of the adsorbate and

159 the carbon surface. Mattson [14], indicated that phenol and its derivatives adsorb on
160 activated carbon via a donor-acceptor complex mechanism that involves carbonyl surface-
161 oxygen groups acting as electron donor and the aromatic ring of the solute acting as an
162 acceptor.

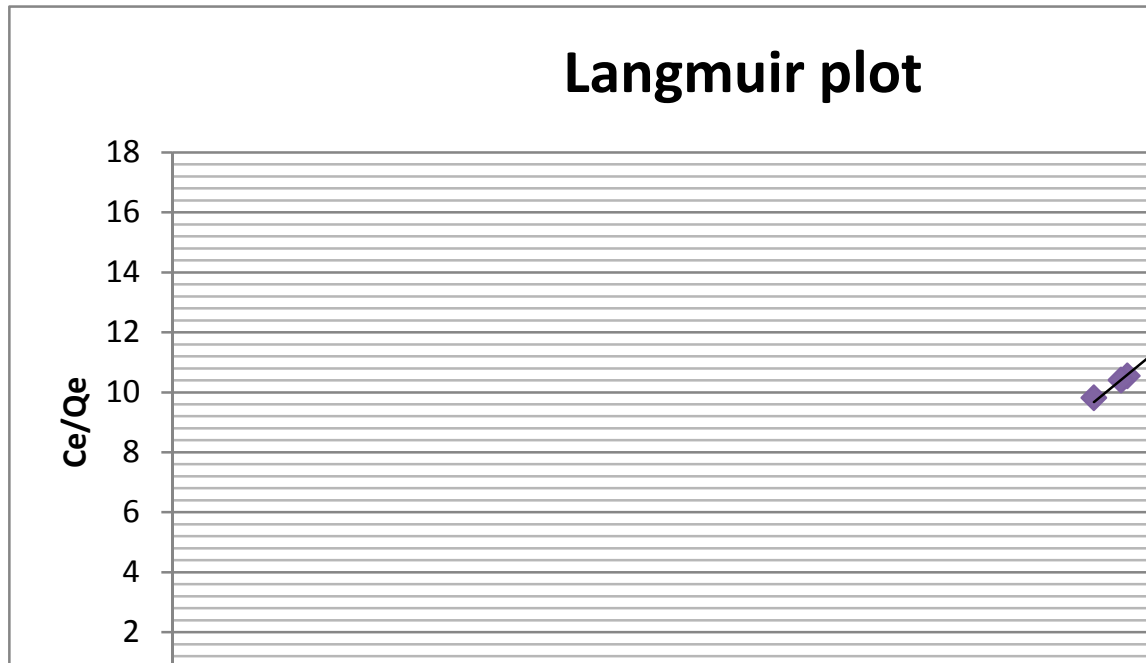
163



164
165

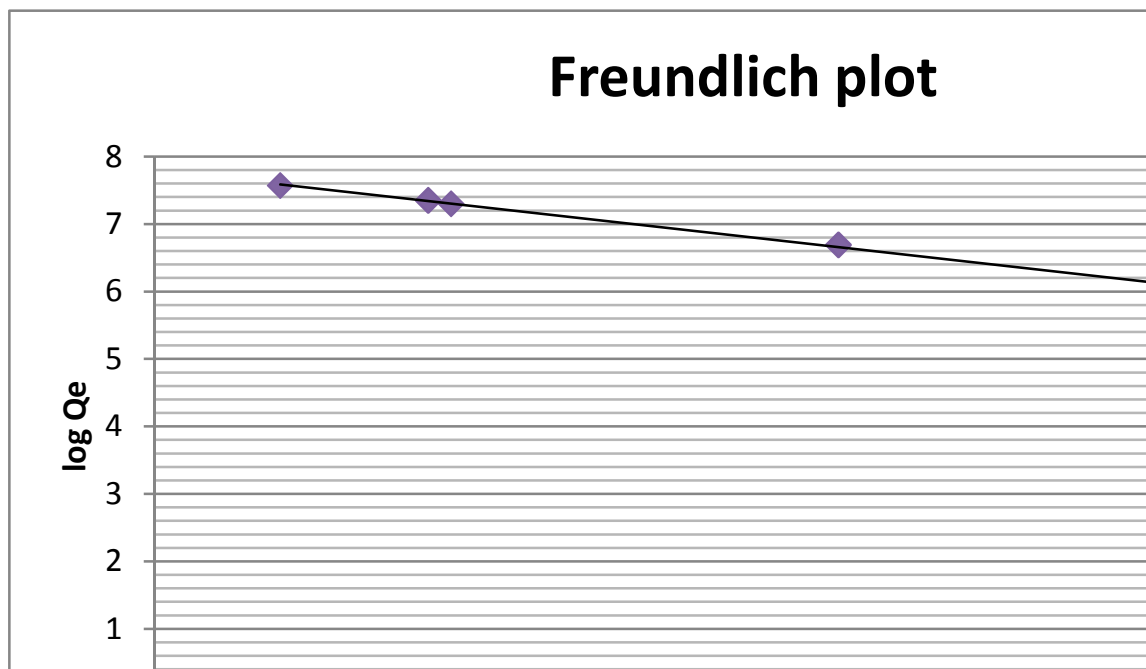
166 **Figure 1: Graph for the effect of pH against adsorption capacity**

167



168
169

170 **Figure 2: Langmuir adsorption isotherm for the effect of pH**



171
172

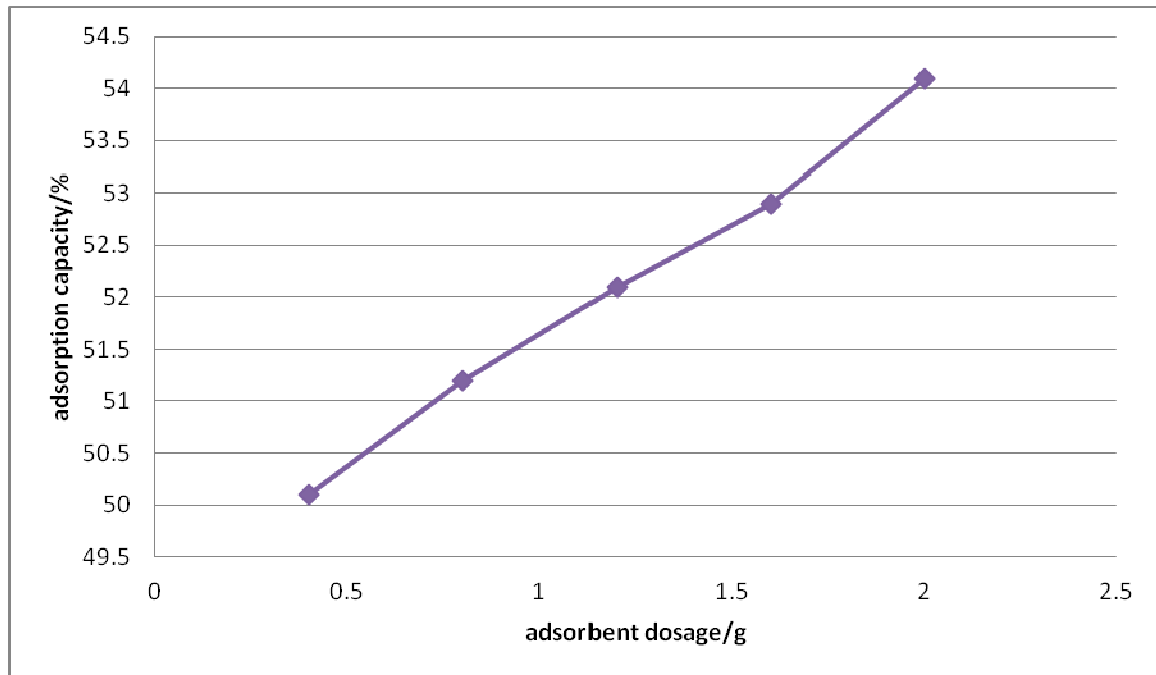
173 **Figure 3: Freundlich adsorption isotherm for the effect of pH**

174

175

176 3.2 EFFECT OF ADSORBENT DOSAGE

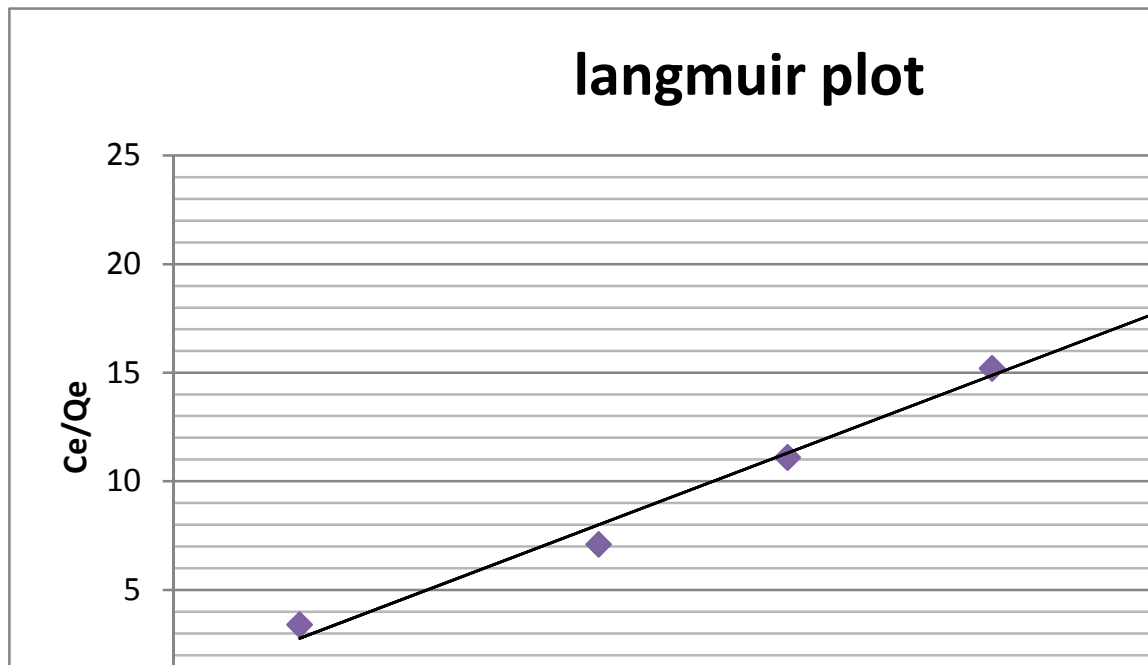
177 The effect of adsorbent dosage was investigated using adsorbent dosages which ranged
178 from 0.4 to 2.0g. This was investigated at the optimum pH 6 and the results showed that as
179 the adsorbent dosage increased the adsorption capacity also increased. The more the
180 adsorbent dosage meant more adsorption sites therefore more phenol was adsorbed .The
181 maximum adsorption capacity was observed for the 2g adsorbent dosage as shown by
182 Figure 4 .According to a study by Srivastava ,[12], the removal of phenol increased with
183 increase in adsorbent dosage.



184
185

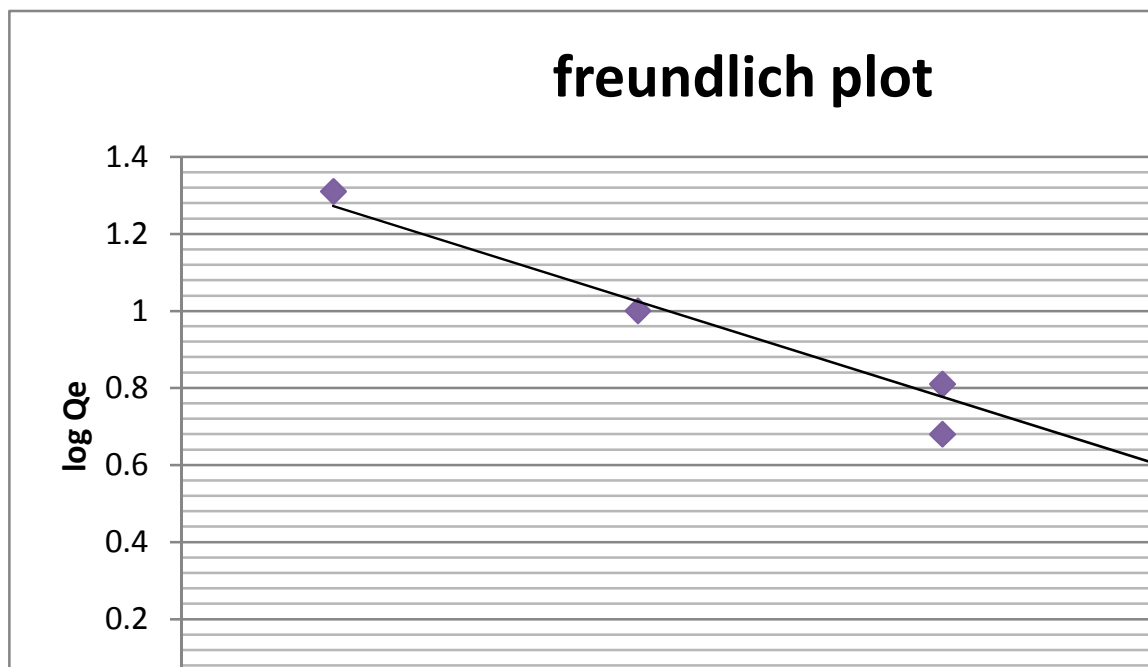
186 Fig 4: Graph of adsorbent dosage against absorption capacity

187



188
189

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



191
192

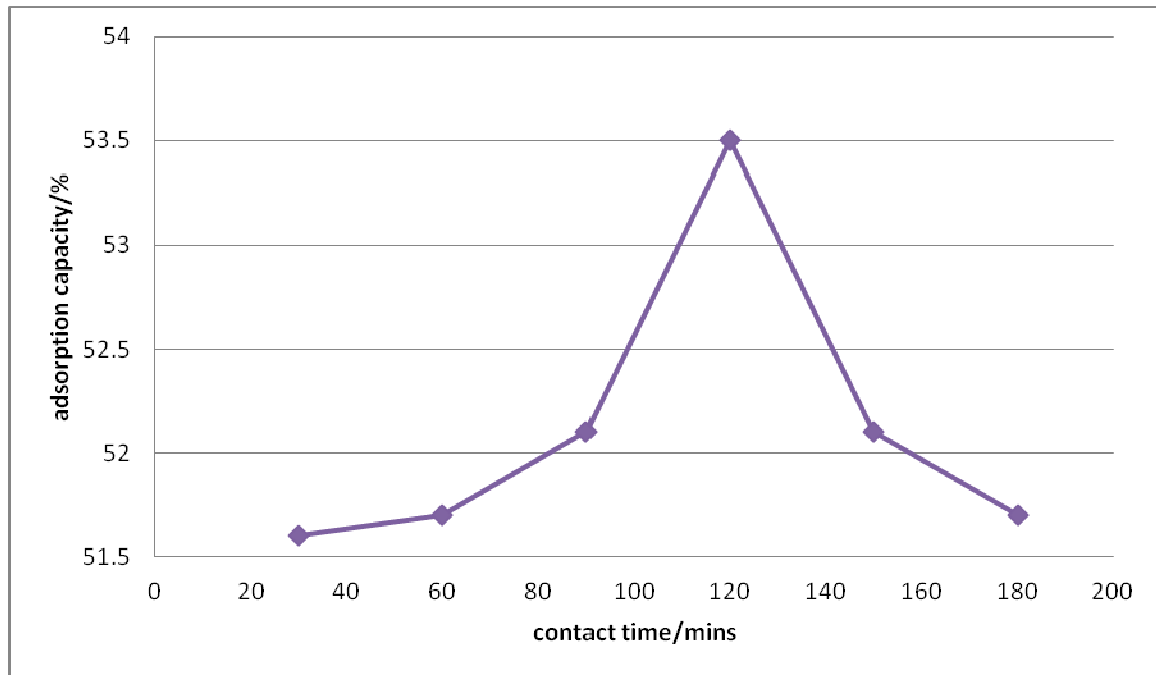
193 **Figure 6: Freundlich adsorption isotherm for the effect of adsorbent dosage**

194

195

196 3.3 EFFECT OF CONTACT TIME

197 The effect of contact time was investigated at pH 6 and an adsorbent dosage of 1.0g. It was
198 noted that as the contact time increased adsorption capacity also increased meaning more
199 phenol was adsorbed with an increase in contact time, this might have been due to the
200 increased number of vacant sites on the adsorbent. However there was a decrease as the
201 contact time increased this might have been caused by the fact that all the adsorbent sites
202 were already occupied. The maximum adsorption capacity was seen after 120
203 minutes.(Fig7). Similar trends were also observed in other investigations [15].

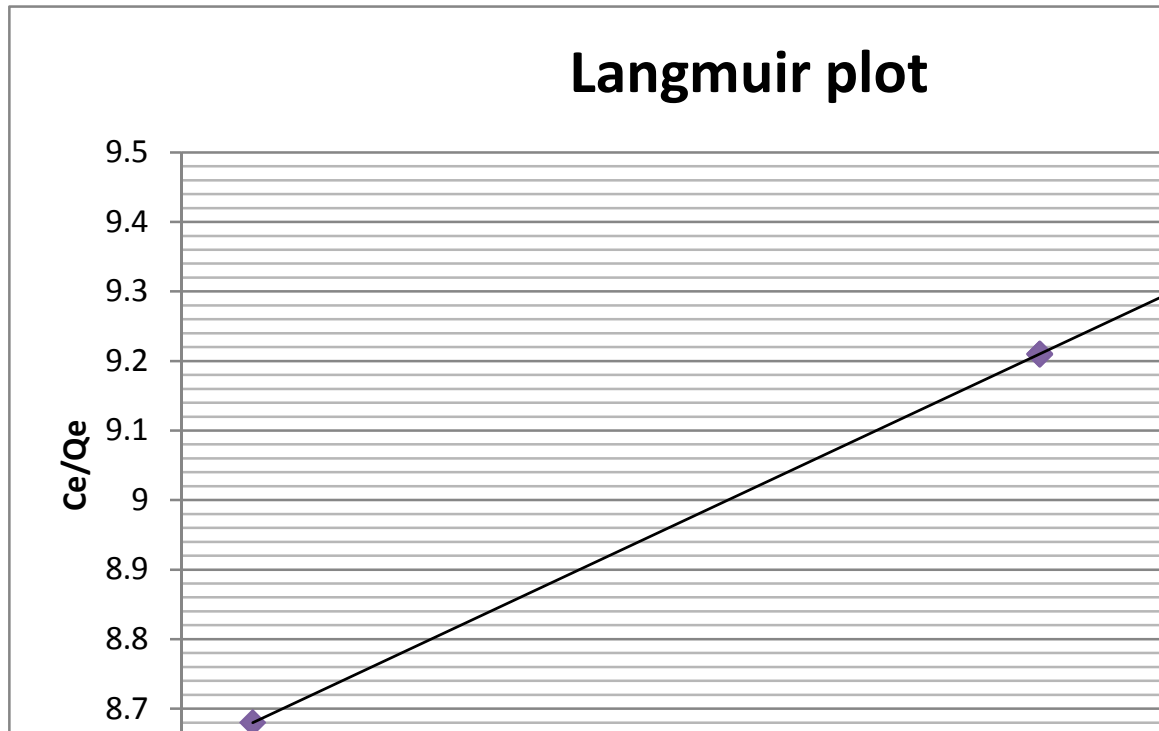


204

205

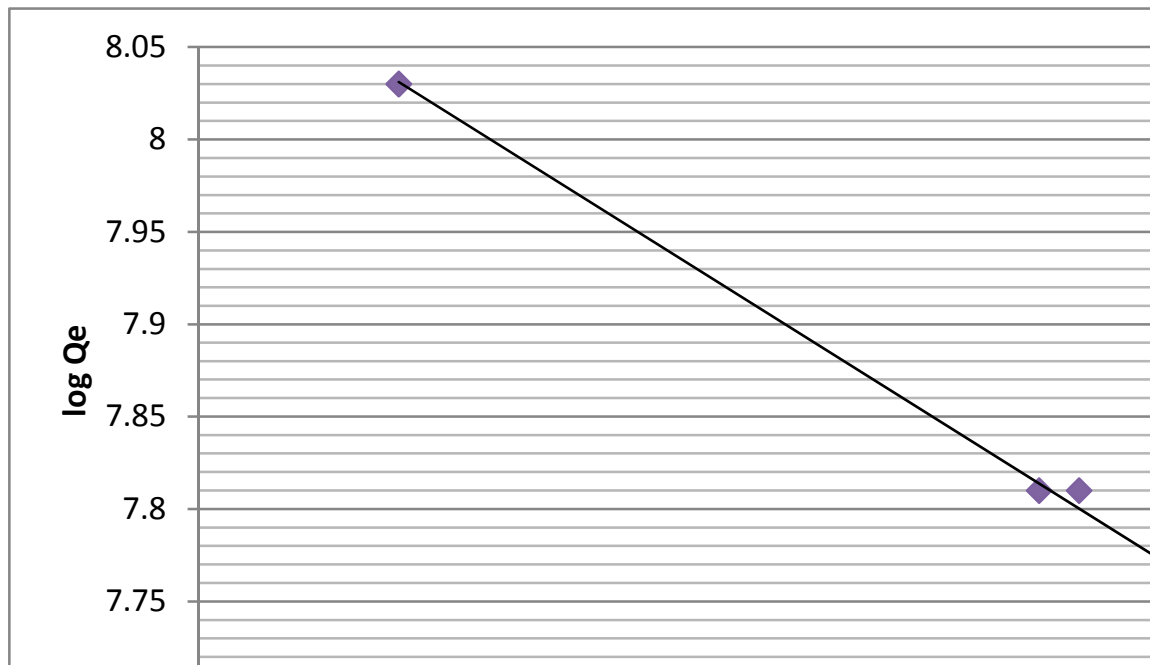
206 Figure 7: Graph of contact time against adsorption capacity

207



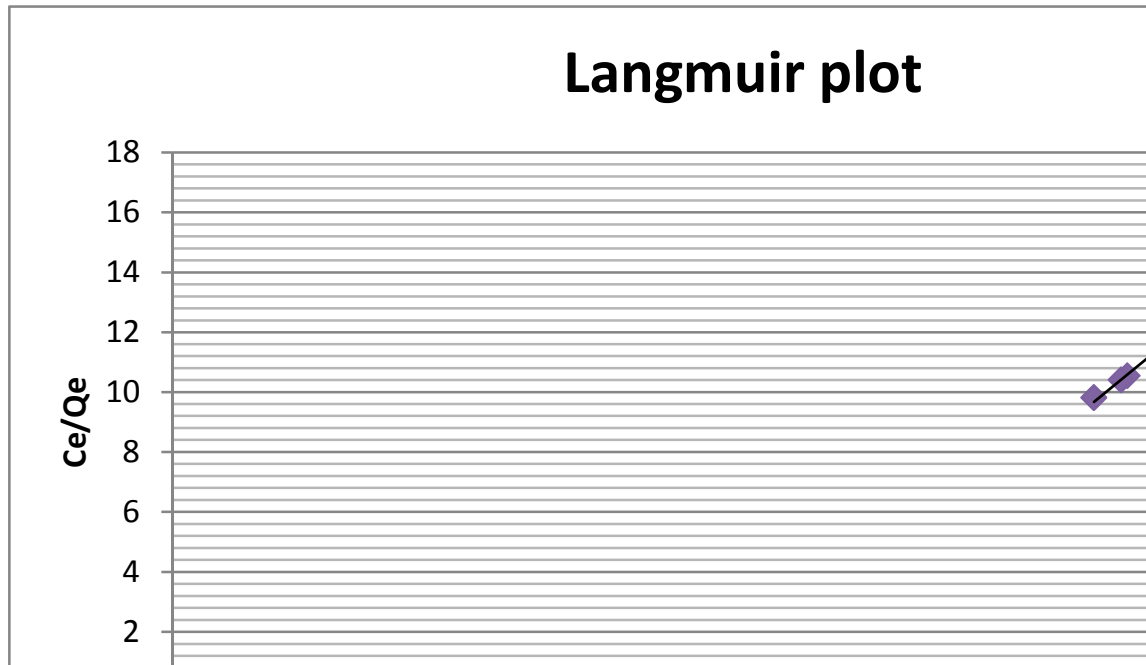
208
209

210 **Figure 8: Langmuir adsorption isotherm for the effect of contact time**



211
212

213 **Figure.9: Freundlich adsorption isotherm for the effect of contact time**



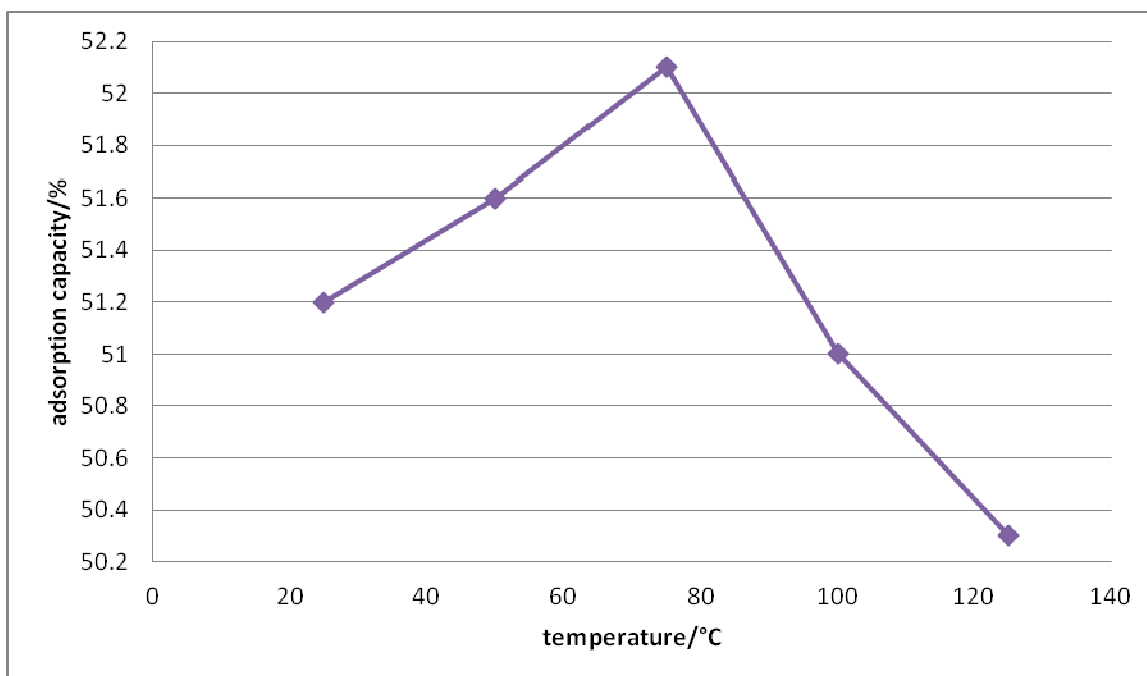
214
215

216

217 3.4 EFFECT OF TEMPERATURE

218 This was investigated at a pH of 6, an adsorbent dosage of 1.0g and contact time was set at
219 1 hour. At the beginning adsorption capacity increased with the increase in temperature as
220 shown by the graph in Figure 10. The adsorption decreases with increasing temperature
221 because theoretically the process of physisorption takes place at low temperature and
222 decreases with increasing temperature. The maximum adsorption capacity was observed
223 at 75°C. A similar trend was also observed by Horsfall and Spiff [16].

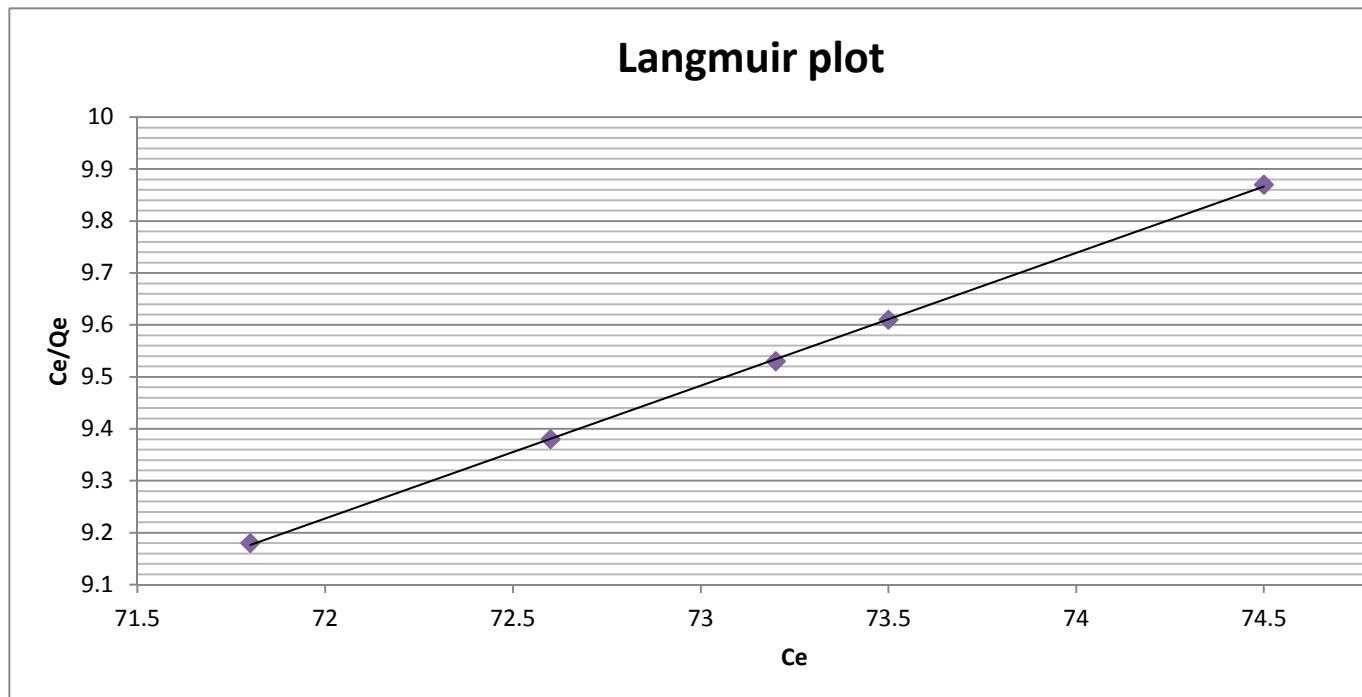
224



225
226

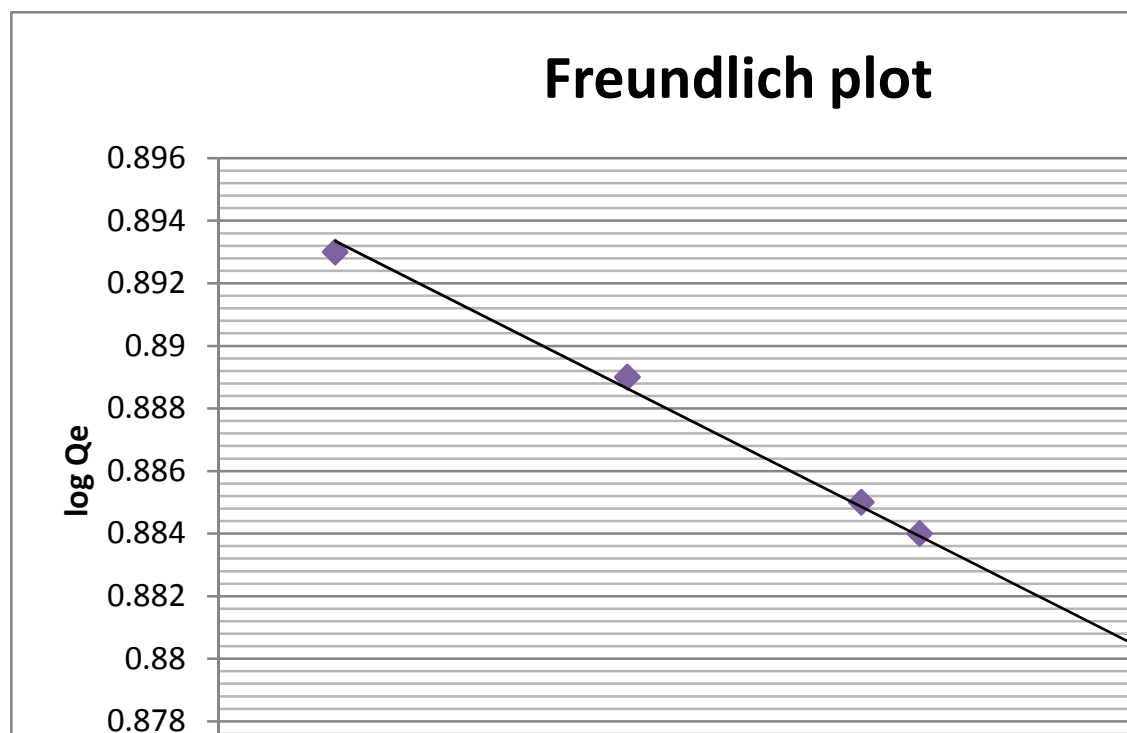
227 **Figure 10: Graph for the effect of temperature against adsorption capacity**

228



229
230

231 **Figure 11: Langmuir adsorption isotherm for the effect of temperature**



232
233
234 **Figure 12: Freundlich adsorption isotherm for the effect of temperature**

235 **Table I : Langmuir adsorption isotherms constants**

	K	R ²
Adsorption dosage	0.01	0.9917
Contact time	0.0297	1
pH	0.0218	0.9957
Temperature	0.0278	0.99998

236

237 The data related to the equilibrium obeyed well the Langmuir modes as seen from the values
 238 of regression coefficients presented in Table 1 , r^2 , ranged from 0.9917-1. The K values
 239 indicates the affinity for binding of phenol. A higher K value was obtained when the contact
 240 time was investigated. Dursun et al [1] reported a K value of 0.0639 at 25°C.

241

242

243

244

245

246

247 **4. CONCLUSION**

248

249 The carbon from maize tassels has great potential as an adsorbent. The results of the study
250 show that the adsorption capacity of the activated carbon Maximum adsorption took place at
251 optimum pH of 6, adsorbent dosage of 2g and at a temperature of 75°C and contact time of
252 120 minutes. The adsorbent was required in large amounts for the process to attain
253 equilibrium faster. Generally the removal of phenol required lower temperatures. The data
254 fitted well into the Langmuir adsorption isotherm and not the Freundlich adsorption isotherm.
255 The Langmuir model assumes that adsorption takes place at specific homogeneous sites on
256 the surface of the adsorbent and also, when a site is occupied by an adsorbate molecule, no
257 further adsorption can take place at this site.

258

259

260 **ACKNOWLEDGEMENTS**

261

262 Authors would like to thank the Chemistry department, Bindura University of Science
263 Education for providing the chemicals and equipment used in this study.

264

265

266

267

268 **COMPETING INTERESTS**

269

270 Authors declare that there are no competing interests

271

272 **AUTHORS' CONTRIBUTIONS**

273

274 Muchanyereyi' designed the study, performed the statistical analysis, wrote the protocol,
275 and wrote the first draft of the manuscript and managed literature searches. 'Chiripayi,
276 Shasha, Mupa' managed the analyses of the study and literature searches. All authors read
277 and approved the final manuscript."

278

279

280

281 **REFERENCES**

282 1. Dursun G, Cicek H, Dursun AY. Adsorption of phenol from aqueous solutions by using
283 carbonized beet pulp. J. hazard. mater. 2005; 125(1):175-182.

284 2. Arellano-Cardenas S, Gallardo-Velazquez T, Osorio-Revilla G, Lopez-Cortez M, Gomez-
285 Perea B. Adsorption of phenol and dichlorophenols from aqueous solutions by porous clay
286 heterostructure. J. Mex. Chem. Soc. 2005; 49(3): 287-291.

287 3. Lin S, Juang R. Adsorption of phenol and its derivatives from water using synthetic resins
288 and low cost natural adsorbents. J. Environmental Management. 2009; 90(3):1336-1349.

- 289 4.Doyurum S, Celik A. Pb (II) and Cd (II) removal from aqueous solutions by olive cake. J.
290 hazard. mater. 2006; 138(1): 22-28
- 291 5. Siva Kumar N, Min K. Removal of phenolic compounds from aqueous solutions by
292 biosorption onto acacia leucocephala bark powder: Equilibrium and kinetic studies. J.
293 Chilean Chemical Society. 2011; 56(1): 539-45
- 294 6.Lakatos J, Brown SD, Snape CE. Coals as sorbents for the removal and reduction of
295 hexavalent chromium from aqueous waste streams. Fuel. 2002; 81(5): 691-98
- 296 7.Mohan D, Pittman CU. Activated carbons and low cost adsorbents for remediation of tri
297 and hexavalent chromium from water. J. hazard. Mater. 2006; 137(2):762-811
- 298 8. Namasivayam C, Yamuna RT. Adsorption of chromium (VI) by a low- cost adsorbent:
299 Biogas residual slurry. Chemosphere.1995; 30: 561-578
- 300 9.Zvinowanda CM, Okonkwo JO, Shabalala PN, Agyei NM. A novel adsorbent for heavy
301 metal remediation in aqueous environments. International Journal of Environmental Science
302 and Technology.2009; 6(3): 425-434.
- 303 10.Zvinowanda CM, Okonkwo JO, Shabalala PN, Agyei NM.Physicochemical
304 characterization of maize tassels as an adsorbent. Part I. Surface Texture, Microstructure
305 and Thermal Stability. J. Applied Polymer Science.2009; 111(4):1923-1930
- 306 11. Shawabkeh RA, Abu-Nameh ESM. Adsorption of phenol and methylene blue by
307 activated carbon from pecan shells. Colloid Journal.2007; 69: 355-359.
- 308 12. Srivastava VC,Swamy MM, Mall ID, Prasad B, Mishra IM. Adsorptive removal of phenol
309 by bagasse fly ash and activated carbon: Equilibrium, kinetics and thermodynamics.Colloids
310 and surfaces A. Physicochemical and Engineering Aspects. 2006; 272(1-2): 89-104
- 311 13.Horsfall JM, Spiff AI. Studies on the effect of pH on sorption of lead and cadmium ions
312 from aqueous solutions by Caladium bicolor(wild cocoyam) biomass.Electron.J.
313 Biotech.2004; 7(3): 1-7
- 314 14. Mattson JS, Mark HB, Malbin MD, Weber WJ, Crittenden JC. Surface chemistry of active
315 carbon: specific adsorption of phenols. J. Colloid and Interface Science.1969; 31(1):116–
316 130.
- 317 15. Uddin MT, Islam MS, Abedin MZ. Adsorption of phenol from aqueous solution by water
318 hyacinth ash. Journal of Engineering and Applied Science.2007; 2(2): 11-17 .
- 319 16.Horsfall JM, Spiff AI. Effect of temperature on the sorption of lead and cadmium ions from
320 aqueous solutions by Caladium bicolor (wild cocoyam)biomass.Electron. J. Biotech. 2005; 8
321 (2): 1-9.

322