

ADSORPTION OF PHENOL FROM AQUEOUS SOLUTION BY SULPHURIC ACID -TREATED 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 activated 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 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.

Keywords: [Phenol , adsorption, Langmuir isotherm, Freundlich Isotherm]

1. INTRODUCTION

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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.

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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, wastewaters from paints, pesticide, coal conversion, resin, petroleum and petrochemical

* Tel.: + 263 0773 410 239.

E-mail address: nmuchanyereyi@gmail.com.

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 activated carbon from sulphuric acid-treated 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].

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125 **3. RESULTS AND DISCUSSION**

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The equation (1) below was used to calculate Q_e

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

129 Where Q_e – equilibrium amount of adsorbate

130 C_o - initial concentration of adsorbate

131 C_e – equilibrium concentration of adsorbate

132 V – volume used

133 M – mass of adsorbent

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

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$$\% \text{ Adsorption capacity} = [(C_o - C_e) / C_o] \times 100 \quad (2)$$

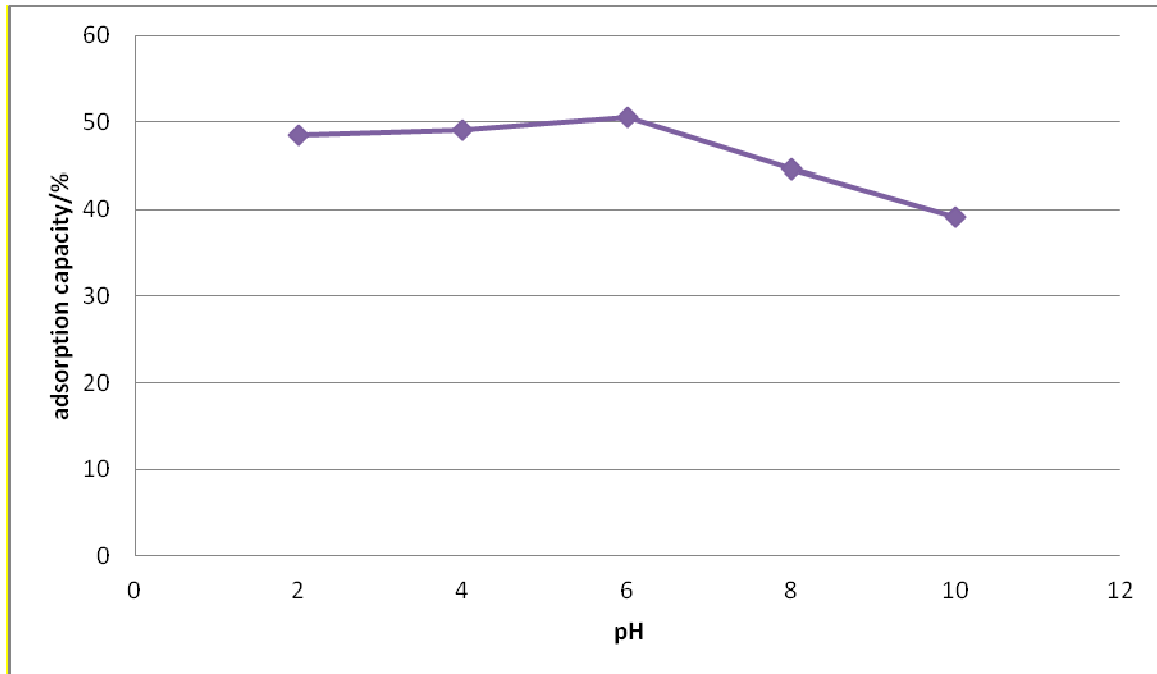
136 3.1EFFECT OF pH

137 The effect of pH was investigated from pH 2-10 and the results obtained showed that
138 as the pH increased the adsorption also increased up to pH 6, then from there the
139 adsorption decreased as pH increased as shown by Figure 1. According to Horsfall
140 [14], adsorption is a pH dependent process and pH dependent binding suggests that
141 phenol is adsorbed by the adsorbent through carboxyl, carbonyl or hydroxyl ligands.
142 The decrease in phenol adsorption from pH = 6 to 2 was due to the increased H^+
143 adsorption on the carbonyl sites, which suppresses phenol adsorption on these sites.
144 On the other hand, the decrease in the phenol amount adsorbed from pH = 6 to 10
145 was probably attributed to both greater solubility of dissociated phenol at $pH > pK_a$
146 and increased repulsion forces between the dissociated form of the adsorbate and
147 the carbon surface. Mattson [14], indicated that phenol and its derivatives adsorb on
148 activated carbon via a donor-acceptor complex mechanism that involves carbonyl surface-
149 oxygen groups acting as electron donor and the aromatic ring of the solute acting as an
150 acceptor.

151 Table I: 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

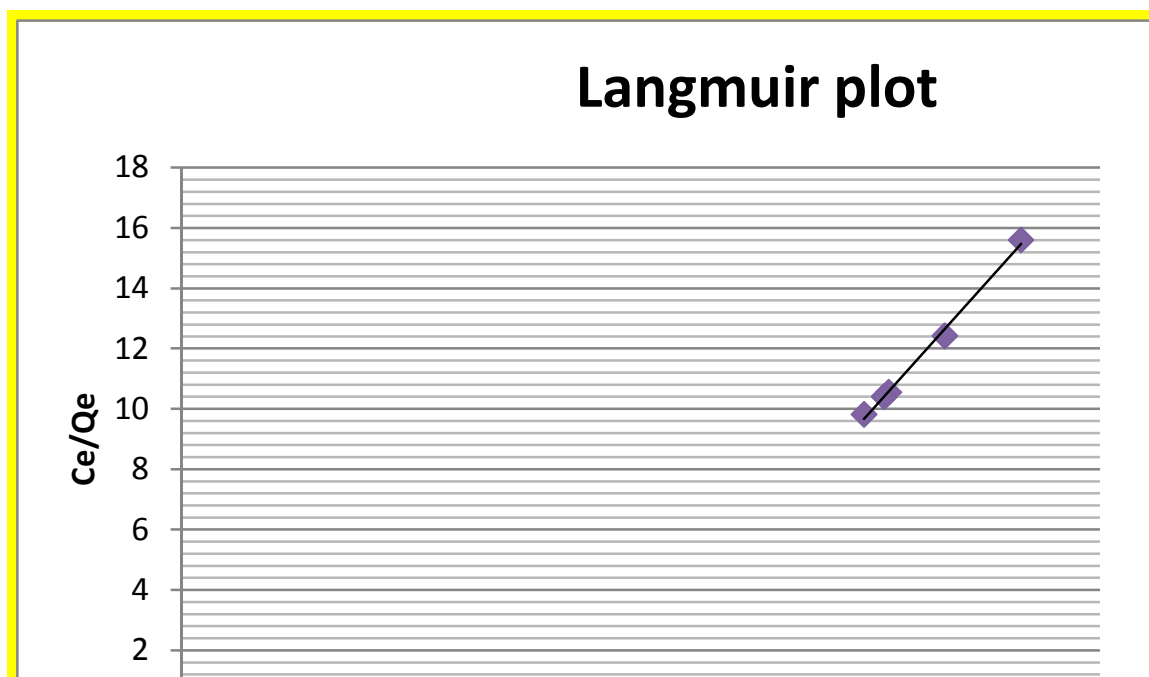
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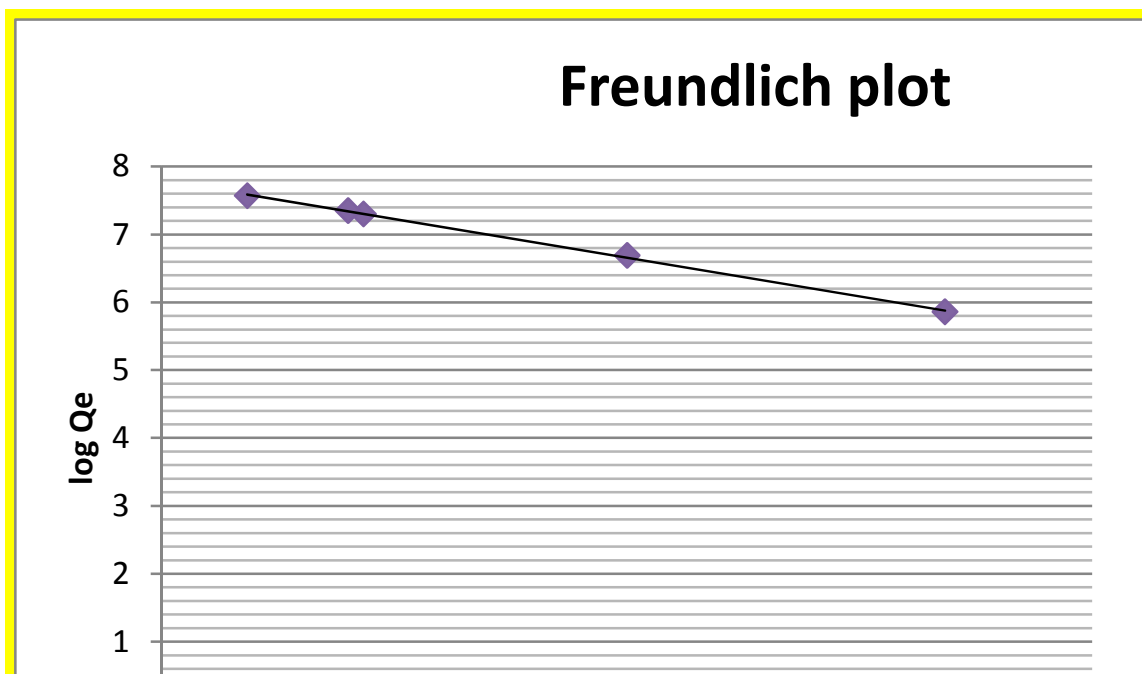
155 **Figure 1: Graph for the effect of pH against adsorption capacity**

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



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

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165 **3.2 EFFECT OF ADSORBENT DOSAGE**

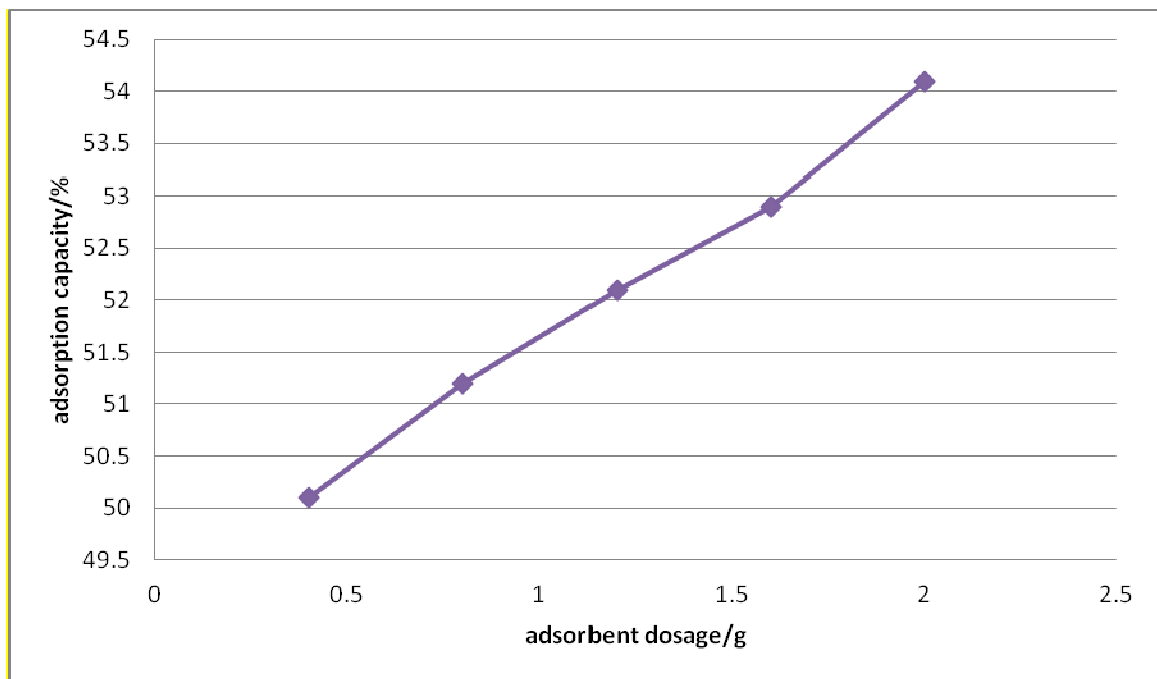
166 The effect of adsorbent dosage was investigated using adsorbent dosages which ranged
 167 from 0.4 to 2.0g. This was investigated at the optimum pH 6 and the results showed that as
 168 the adsorbent dosage increased the adsorption capacity also increased. The more the
 169 adsorbent dosage meant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

173 **Table II: 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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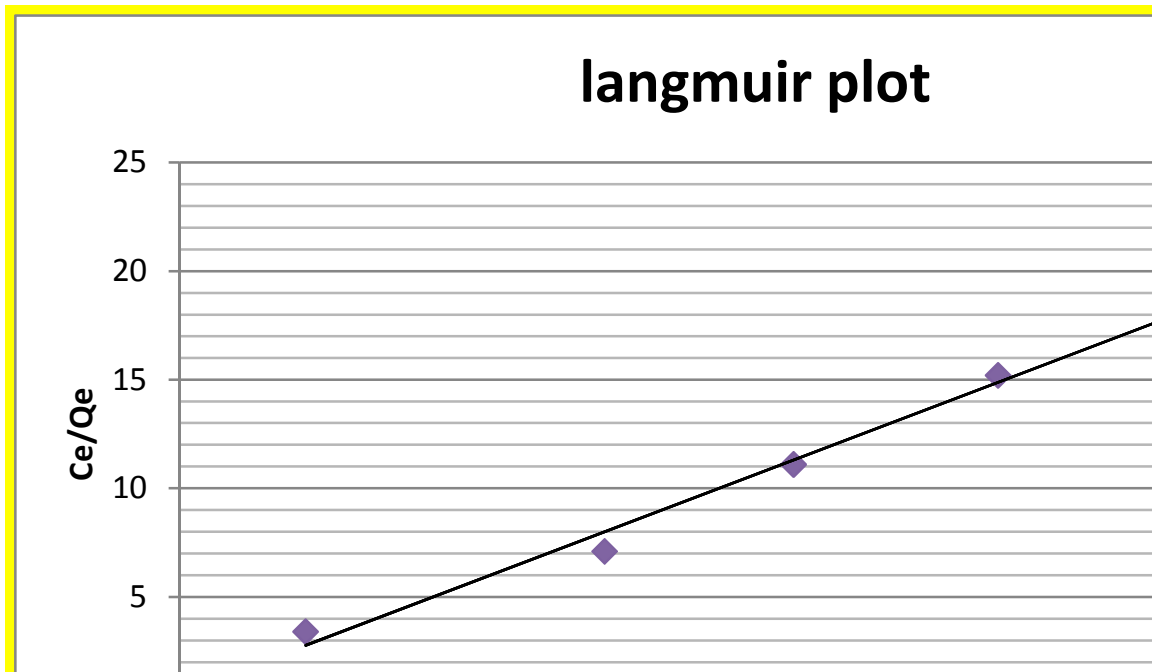
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177 **Fig 4: Graph of adsorbent dosage against absorption capacity**

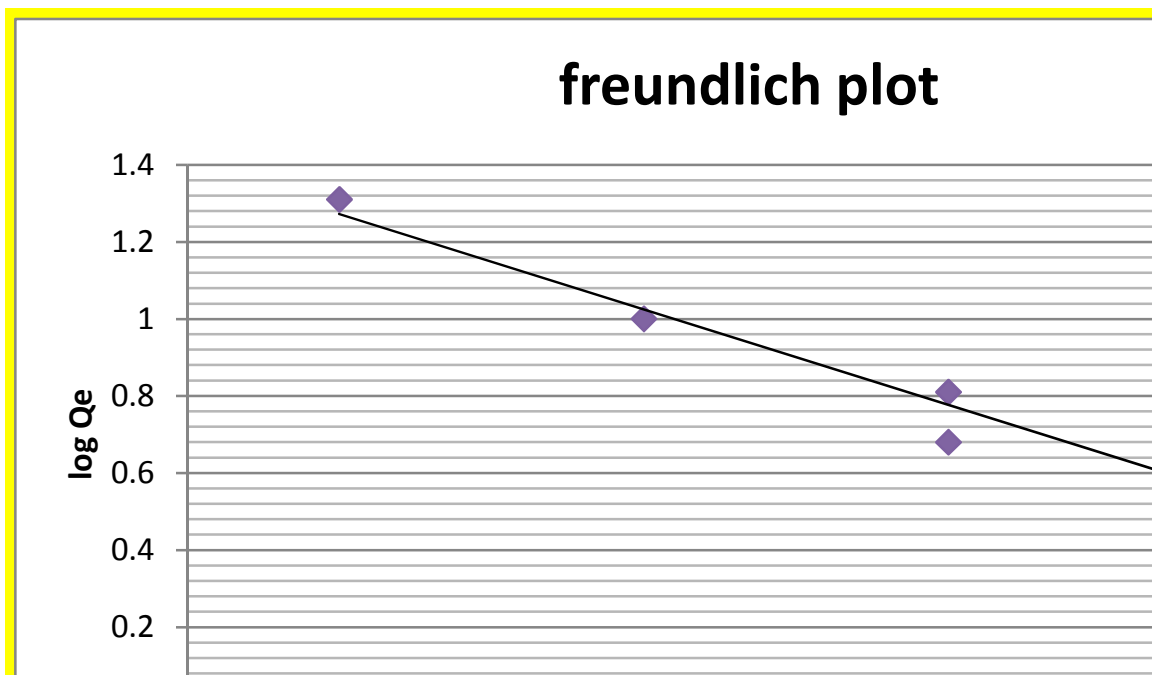
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Figure 5: Langmuir adsorption isotherm for the effect of adsorbent dosage



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

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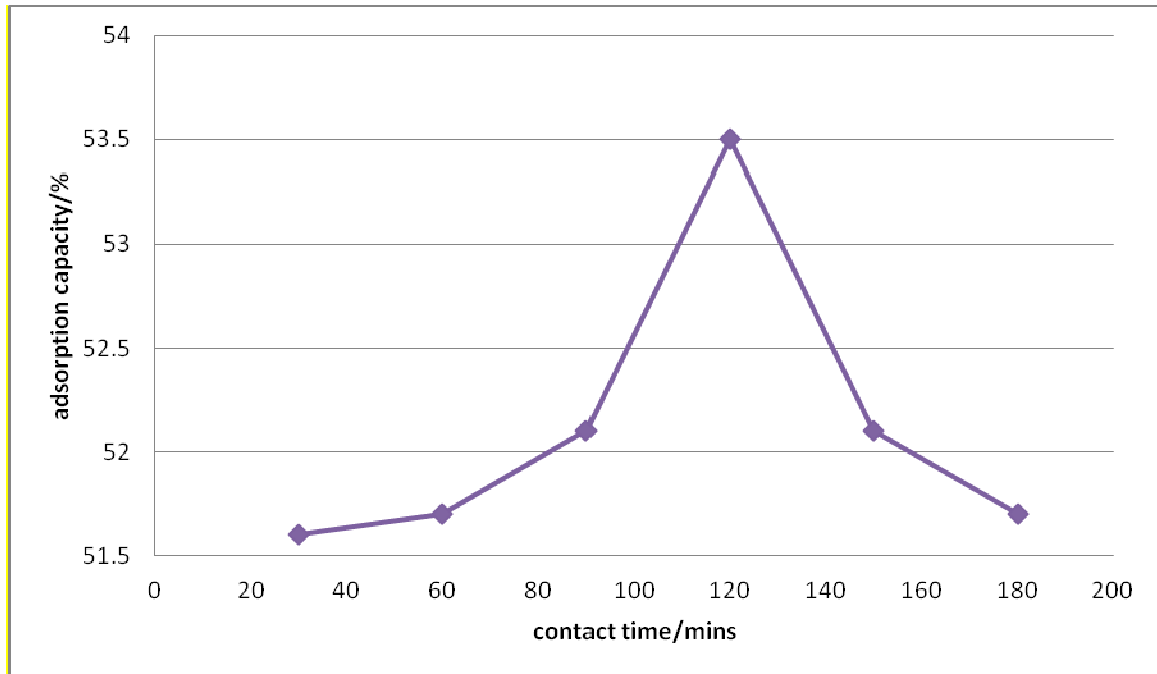
187 3.3 EFFECT OF CONTACT TIME

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

195 **Table III: The effect of contact time**

Contact time	C _o (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

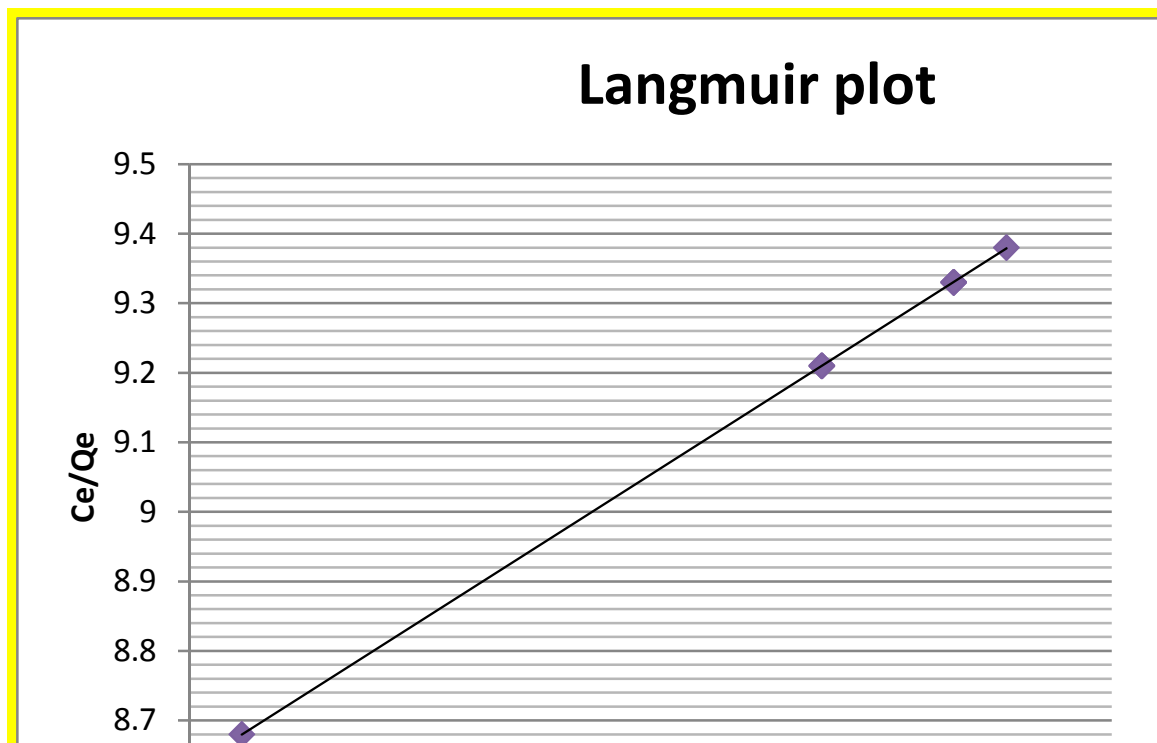
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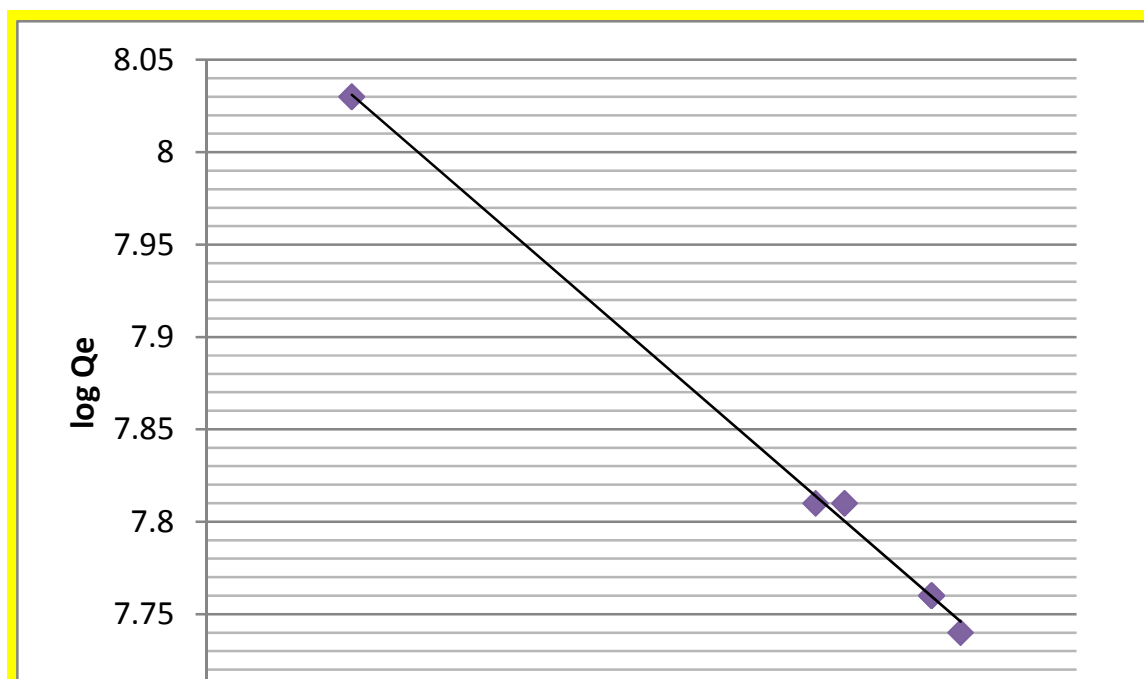
199 **Figure 7: Graph of contact time against adsorption capacity**

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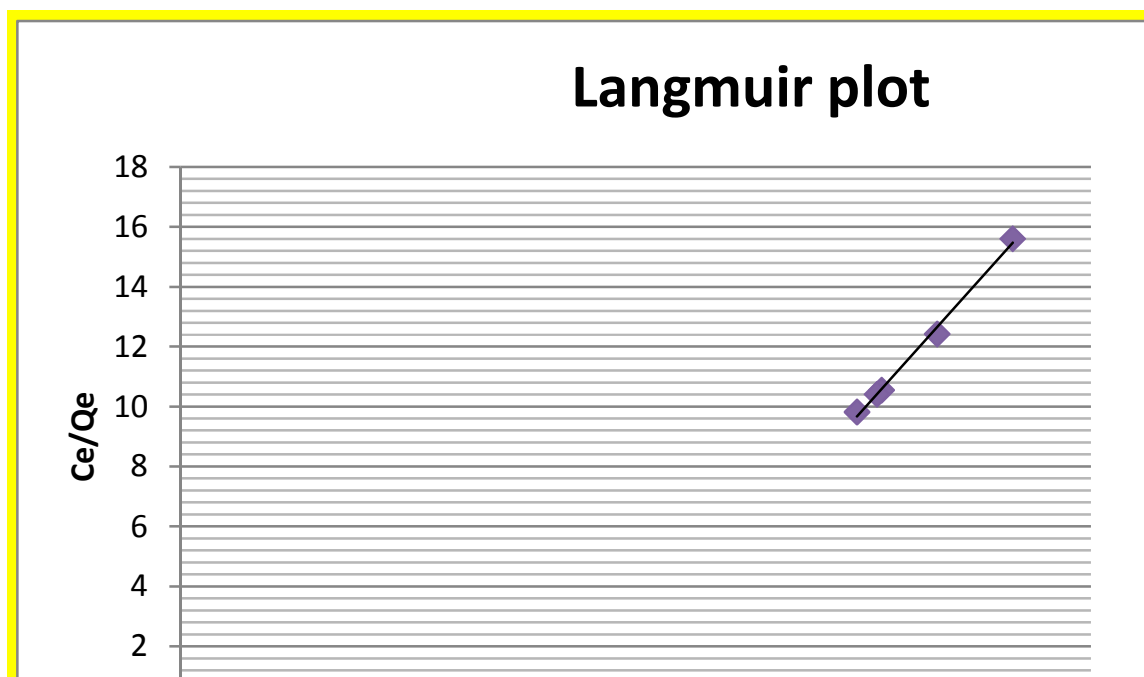


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203 **Figure 8: Langmuir adsorption isotherm for the effect of contact time**



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



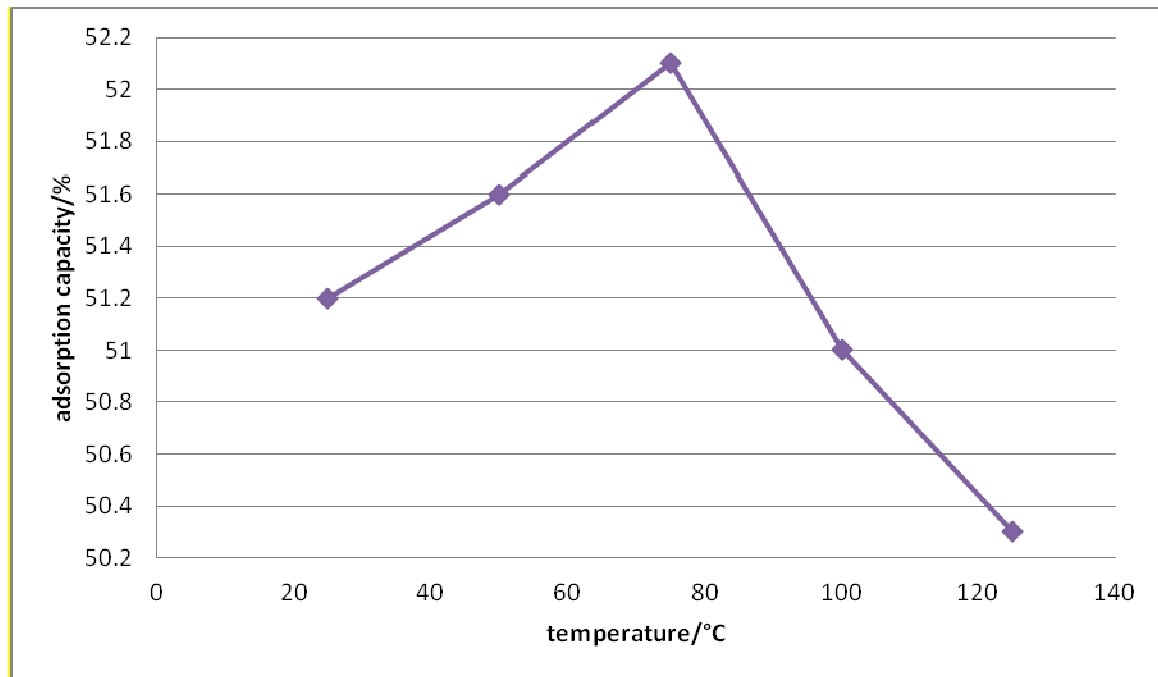
3.4 EFFECT OF TEMPERATURE

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 10. 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 [16].

Table IV: The effect of temperature

Temperature	C_o (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
125	150	74.5	7.55	9.87	50.3

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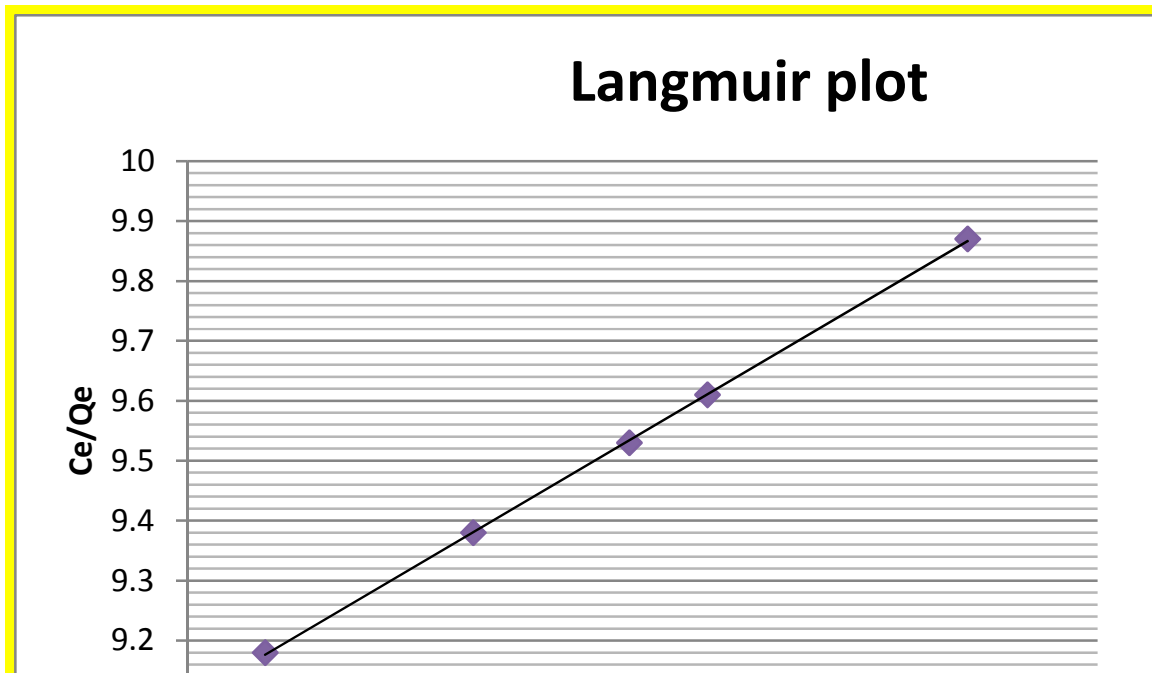


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Figure 10: Graph for the effect of temperature against adsorption capacity

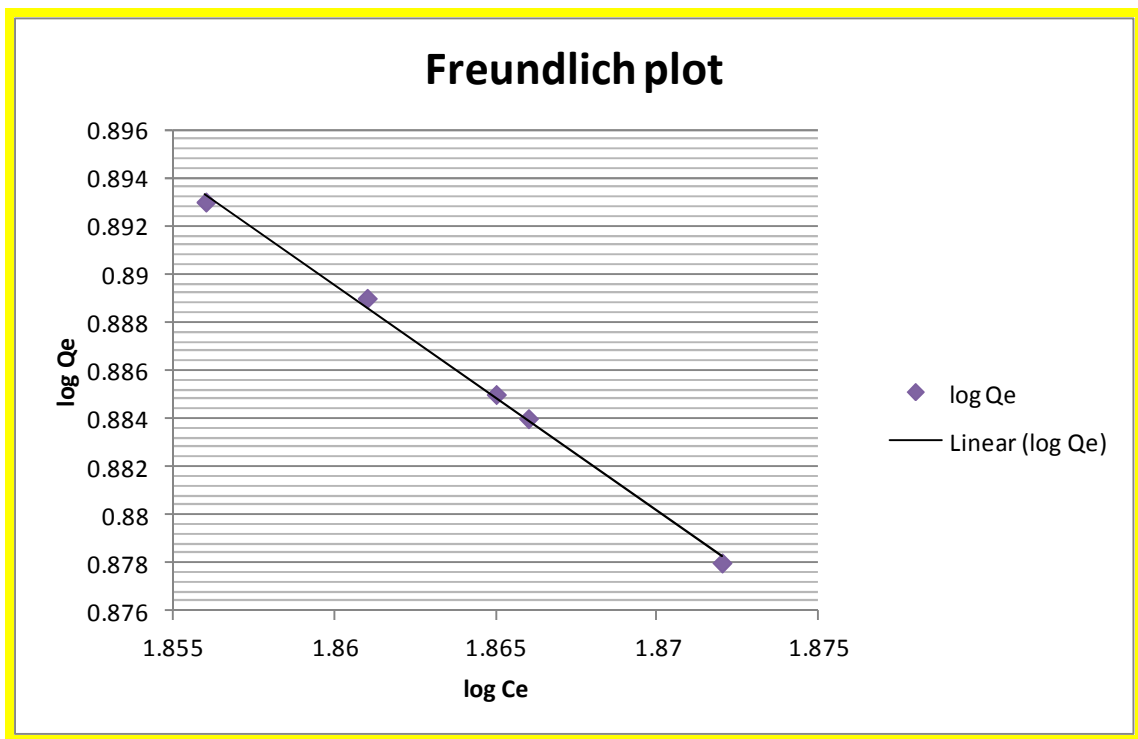
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225 **Figure 11: Langmuir adsorption isotherm for the effect of temperature**



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Figure 12: Freundlich adsorption isotherm for the effect of temperature

4. CONCLUSION

The carbon from maize tassels has great potential as an adsorbent. The results of the study show that the adsorption capacity of the activated carbon 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.

ACKNOWLEDGEMENTS

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

COMPETING INTERESTS

Authors declare that there are no competing interests

AUTHORS' CONTRIBUTIONS

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

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