INTRODUCTION

Disposal of steel industry wastewater pose one of the major problems, because such effluents contain a number of contaminants including acid or base, dissolved solids, toxic compounds, and color. Out of these, color is the first contaminant to be recognized because it is visible to the human eye. Removal of Cu (II) ions by conventional waste treatment methods is difficult since these are stable to light and oxidizing agents and are resistant to aerobic digestion. Possible methods of color removal from textile effluents include chemical oxidation, froth flotation, adsorption, coagulation, etc. Among these, adsorption currently appears to offer the best potential for overall treatment, and it can be expected to be useful for a wide range of compounds, more so than any of the other listed processes. Recognizing the high cost of activated nano carbon, many investigators have studied the feasibility of cheap, commercially available materials as its possible replacements. Such materials range from industrial waste products such as waste rubber tyres, blast furnace slag, and lignin to agricultural products such as wool, rice straw, coconut husk, saw dust, and peat moss. Fertilizer plants generate waste slurry due to liquid fuel combustion, and this causes a disposal problem. The waste slurry is converted into a cheap carbonaceous adsorbent and used for the removal of Cu (II) ions and phenols. Steel plants produce granular blast furnace slag as a byproduct, and this material also causes a disposal problem. Presently this is being used as filler. Efforts have been made to convert this waste into a potential and low-cost adsorbent.

In the present investigation the adsorption of Cu (II) ion on activated nano carbon prepared from Strychnos nux-vomica L Leaves by carbonization with sulphuric acid has been achieved. The kinetic and equilibrium adsorption data obtained were utilized to characterize the sample prepared. The amounts and rates of adsorption of copper using above activated nano carbon from water were then measured. Three simplified kinetic models including pseudo first order, Pseudo second order equations and Elovich equations were used to describe the adsorption process.

MATERIALS AND METHODS

Chemicals

All reagents used in the experiments were of analytical (AR) grade and were obtained from Scientific Equipment Company, Trichy. Stock solutions of the test reagents were prepared by dissolving the Cu (II) ions in distilled water. 1000 mg/L of stock solution of copper (II) (CuSO₄, 5H₂O) was prepared by dissolving accurately weighed 3.9296 grams of copper sulphate in 1000 ml distilled water. All experimental solutions were prepared by diluting the stock solution to the required concentration. The pH of each experimental solution was adjusted to the required initial pH value using dilute HCl (or) NaOH before mixing the adsorbent. The concentration of residual Cu (II) ion was determined with atomic absorption spectrophotometer (Perkin Eimer 2380).

Abstract:

The effective and economic removal of heavy metals from industrial effluents is one of the important issues globally. The present study proposed the use of Activated Strychnos nux-vomica L in the removal of Cu (II) ions from synthetic aqueous solutions. Batch adsorption experiments were carried to fix the adsorption dosage and also to find the optimum pH. Batch adsorption studies showed that Activated Strychnos nux-vomica L was able to adsorb Cu (II) ions from aqueous solutions in the concentration range 25–125 mg/L. The adsorption was favored with maximum adsorption at pH 6.5, whereas the adsorption starts at pH 2 for Cu (II) ions. The effects of contact time, initial concentration of Cu (II) ions, adsorbent dosage and temperature have been reported. The applicability of Langmuir and Freundlich isotherm was tried for the system to completely understand the adsorption isotherm processes. The adsorption kinetics tested with pseudo-first-order and pseudo-second-order models yielded high R² values from 0.850 to 0.932 and from 0.991 to 0.999, respectively. The Activated Strychnos nux-vomica L was found to be cost effective and has good efficiency to remove these toxic Cu (II) ions from aqueous solution.

Key Words: Copper (II) ion, Activated Strychnos nux-vomica L (ASNVL), Langmuir, Freundlich isotherms and kinetics.
Preparation of adsorbent

The natural plant material Strychnos nux-vomica L used in the present investigations was collected from Edyappatti nearby pudukkottai district. The leaves were washed with distilled water several times to remove the dirt and dust and was subsequently dried in a hot air oven at 110°C. Afterward, carbonization of the Strychnos nux-vomica L was carried out by w/v ratio of concentrated sulphuric acid for 1 hour, which was afterward mixed with Zinc chloride. Zinc chloride acts as a catalyst in the process. The primary carbon was activated at 1000°C for 5 hrs under optimized conditions to obtain activated nano carbon. The activated nano carbon was thereafter looked to room temperature in an insert atmosphere of nitrogen and washed with hot distilled water and 0.5 N Hydrochloric acid until the pH of the material reached 7.0 the activated nano carbon was also dried in a hot air oven at 110°C, ground and sieved to obtain the desired particulate size (150mm) and stored in desiccators for further use.

Batch Adsorption studies

Preliminary batch adsorption studies were conducted to determine the equilibrium time. Batch studies were performed by mixing 0.025g of Cu (II) ion with some of solution of different initial concentrations of Cu (II) ion in 250 ml stoppered conical flask. The dose of adsorbent was decided experimentally. All the adsorption experiments were conducted at 30° to 60°C, at an agitation speed of 150 rpm on the thermostat sharing water bath, the progress of adsorption was noted and equilibrium was achieved in 50 min. After equilibrium, the adsorbent was separated from the aged use phase by centrifugation at 1000 rpm for to min using a centrifuge (Remi 24, India). The residual concentration of Cu (II) ions in the supernatant was determined by a UV–Visible spectrophotometer at 618nm. The percentage removal of Cu (II) ions at equilibrium and the amount of Cu (II) ions transferred onto the surface of the adsorbent, q_e (mg/g) was calculated using the following relationships.

\[
\text{Percentage metal removal} = 100 \left(\frac{C_0 - C_e}{C_0}\right)
\]

\[
Q_e = \frac{(C_0 - C_e) \cdot V}{w}
\]

Where, \(C_0\) (mg/L) is the initial concentration of Cu (II) ion, \(C_e\) (mg/L) is the equilibrium concentration of Cu (II) ions, V is the volume of the solution (L), and w (g) is the mass of the adsorbent.

RESULT AND DISCUSSION

Characterization of Adsorbent

Effect of operating variables on the adsorption of Cu (II) ions onto Activated Strychnos nux-vomica L the adsorbent of materials, ASNVL were used to absorb some mg of Cu (II) ion respectively.

The adsorption capacity of ASNVL is better than other, with the increase amount of ASNVL the removal of Cu (II) increased obviously.

Effect it contact time

Figure 1 illustrates the effects of contact time on the removal of Cu (II) ion respectively for different initial Cu (II) ions concentrations; the changes in contact time exhibit approximately the same effects on the Cu (II) ion. Because of the utilization of the readily available active adsorption sites on the as surface\(^1\), the adsorption of Cu (II) ions was rapid for the first 30 min for all the investigated initial Cu (II) ions concentrations. There after it continued at a slower rate and finally reached equilibrium as a result of saturation it as surface sites, for all three Cu (II) ions, at all of the stored initial Cu (II) ions concentrations a sufficient contact time was determined as 30 min.

Table 1: Characteristics of the Adsorbent

<table>
<thead>
<tr>
<th>Properties</th>
<th>ASNVL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle size (mm)</td>
<td>0.0150</td>
</tr>
<tr>
<td>Density (g/cc)</td>
<td>0.2005</td>
</tr>
<tr>
<td>Moisture content (%)</td>
<td>0.2527</td>
</tr>
<tr>
<td>Loss in ignition (%)</td>
<td>0.0110</td>
</tr>
<tr>
<td>pH of aqueous solution</td>
<td>6.5000</td>
</tr>
</tbody>
</table>

Table 2: Equilibrium Parameters for the Adsorption of Cu (II) ion onto ASNVL

<table>
<thead>
<tr>
<th>M0</th>
<th>Ce (Mg / L)</th>
<th>Qe (Mg / L)</th>
<th>Removal %</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>2.6412</td>
<td>2.6541</td>
<td>44.702</td>
</tr>
<tr>
<td>50</td>
<td>5.4456</td>
<td>5.8453</td>
<td>122.34</td>
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<tr>
<td>75</td>
<td>13.834</td>
<td>12.891</td>
<td>126.38</td>
</tr>
<tr>
<td>100</td>
<td>26.743</td>
<td>25.647</td>
<td>128.61</td>
</tr>
<tr>
<td>125</td>
<td>45.848</td>
<td>40.336</td>
<td>126.18</td>
</tr>
</tbody>
</table>

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**Effect of adsorbent concentration**

ASNVL with different concentrations were combined with a fixed 50ml, 50 mg/L of Cu (II) ion respectively the adsorption of Cu (II) ions increased with the increase of absorbent dose, and reached to a plateau at the appropriate dose of 125 mg of ASNVL. The results were shown in the fig. 2.

**Effect of intoned pH on adsorption**

The pH value of the solution was important controlling parameters in the adsorption process, the removal of Cu (II) ions increase significantly with increasing pH from 1 to 7. The removal efficiencies of Cu (II) ions were low at pH<4. The obvious decreasing of removal might be attributed to the repulsive forces between the positive surface charge of adsorbate and the positive Cu (II) ions. The result shows that the fig 3.

**pH optimization**

The removal of Cu (II) at different pH was studied in batch mode. A 50 ml of test solution of fixed concentrations was treated with 0.025 g of ASNVL and agitated intermittently for 60 min. The contact time and conditions were selected on the basis of preliminary experiments, which demonstrated that equilibrium was established in 60 min. After this period the solutions then both phases were separated by filtration. The Cu (II) ion content of the filtrate was determined by atomic spectrometry. The Cu (II) ions concentration retained in the sorbent phase (q_e, mg/g) was calculated by using Eq. (1)

\[ q_e = \frac{(C_0 - C_e) V}{m} \]  

Where, \( C_0 \) and \( C_e \) are the initial and final (equilibrium) concentrations of the Cu (II) ion in solution (M), V the solution volume (L) and m is the mass of Activated Strychnos nux-vomica L (g).

**Adsorption Kinetic and isotherm models**

**Adsorption Isotherms:** Adsorption isotherms describe the interaction of adsorbate with adsorbers. The experimental adsorption data of Cu (II) ions on the Activated Strychnos nux-vomica L were analyzed by Langmuir and Freundlich isotherms.

**Langmuir Isotherm:** The Langmuir adsorption model is based on the assumption that maximum adsorption corresponds to a saturated monolayer of solute molecules on the adsorbent surface, with no lateral interaction between the adsorbed molecules. The Langmuir adsorption isotherm has been successfully used in many monolayer adsorption processes, the values are in table 3. The adsorption isotherm data were analyzed by the Langmuir isotherm model in the linearized form.
Table 3: Langmuir and Freundlich Isotherm Parameter for the Adsorption of Cu (II) ion onto ASNVL

<table>
<thead>
<tr>
<th>Temp. (°C)</th>
<th>Langmuir Parameters</th>
<th>Freundlich Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Qm</td>
<td>b</td>
</tr>
<tr>
<td>30°C</td>
<td>183.02</td>
<td>0.1444</td>
</tr>
<tr>
<td>40°C</td>
<td>204.13</td>
<td>0.1154</td>
</tr>
<tr>
<td>50°C</td>
<td>314.96</td>
<td>0.0626</td>
</tr>
<tr>
<td>60°C</td>
<td>205.77</td>
<td>0.1316</td>
</tr>
</tbody>
</table>

Table 4: Dimensionless Separation Factor (R_L) for the Adsorption of Cu (II) ion onto ASNVL

<table>
<thead>
<tr>
<th>Temperature °C</th>
<th>30°C</th>
<th>40°C</th>
<th>50°C</th>
<th>60°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>0.2168</td>
<td>0.2572</td>
<td>0.3896</td>
<td>0.2330</td>
</tr>
<tr>
<td>50</td>
<td>0.1216</td>
<td>0.1476</td>
<td>0.2419</td>
<td>0.1318</td>
</tr>
<tr>
<td>75</td>
<td>0.0845</td>
<td>0.1034</td>
<td>0.1754</td>
<td>0.0919</td>
</tr>
<tr>
<td>100</td>
<td>0.0647</td>
<td>0.0796</td>
<td>0.1376</td>
<td>0.0706</td>
</tr>
<tr>
<td>125</td>
<td>0.0524</td>
<td>0.0647</td>
<td>0.1132</td>
<td>0.0572</td>
</tr>
</tbody>
</table>

\[
\frac{C_d}{q_e} = \frac{C_0}{q_{max}} + 1/(b q_{max})
\]  \hspace{2cm} (4)

Where, \( q_e \) is the equilibrium adsorption capacity of the adsorbent (mg/g), \( C_0 \) is the equilibrium Cu (II) ion concentration in solution (mg/l), \( q_{max} \) is the maximum amount of Cu (II) ion that could be adsorbed on the adsorbent (mg/L) and b is the Langmuir adsorption equilibrium constant (L/mg). In order to find out the feasibility of the isotherm, the essential characteristics of the Langmuir isotherm can be expressed in terms of dimensionless constant separation factor \( R_L \) by the equation

\[
R_L = \frac{1}{1+(b C_0)}
\]  \hspace{2cm} (5)

Where, \( C_0 \) (mg/L) is the highest initial concentration of adsorbent and b (L/mg) is Langmuir isotherm constant. The parameter \( R_L \) indicates the nature of shape of the isotherm accordingly.

\( R_L > 1 \) Unfavorable adsorption
\( 0 < R_L < 1 \) Favorable adsorption
\( R_L = 0 \) Irreversible adsorption
\( R_L = 1 \) Linear adsorption

The \( R_L \) values between 0 to 1 indicate favorable adsorption for all initial concentration (\( C_0 \)) and temperatures studied. The calculated \( R_L \) values are given in table 4. The values of b were increased with increasing the dose of adsorbent for ASNVL. High b values indicate high adsorption affinity the monolayer saturation capacity \( Q_m \) were around 205 mg/L for ASNVL.

**Freundlich Isotherm**

The Freundlich model can be applied to multilayer adsorption with non-uniform distribution of adsorption heat and affinities over the heterogeneous surface\(^{16}\). The experimental data were analyzed by Freundlich isotherm model in the linearized form,

\[
\log q_e = \frac{1}{n} \log C_0 + \log K_f
\]  \hspace{2cm} (6)

Where, \( K_f \) is the Freundlich adsorption constant and it is the maximum adsorption capacity of Cu (II) ions (mg/g) and \( n \) is the constant illustrates the adsorption intensity (dimensionless). The values tabulated in table 3 shows the favorability of adsorption.

**Kinetic studies**

The kinetic adsorption data were evaluated to understand the dynamics of the adsorption reaction in terms of the order of the rate constant batch experiments were conducted to explore the rate of Cu (II) ion adsorption by Activated Strychnos nux-vomica L as described in adsorption isotherms section at pH 7. Three kinetic models were applied to the adsorption kinetic data in order to investigate the behavior of adsorption process of Cu (II) ion onto the adsorbents. These models include the pseudo first order Kinetics (reversible or irreversible), the pseudo – Second – order and the intra particle diffusion models the linear form of reversible pseudo – first – order model can be formulated as:

\[
\ln \left( \frac{q_e}{q_t} \right) = \ln q_e - k_1 t
\]  \hspace{2cm} (7)

Where, \( q_e \) (mol/g) and \( q_t \) (mole/g) are the amount of Cu (II) ion adsorbed at equilibrium and at time \( t \), respectively and \( K_1 \) (min\(^{-1}\)) is the rate constant \( K_1 \) values were evaluated from the linear regression of \( \ln (q_e/q_t) \) versus data. Linear from of irreversible pseudo first order model can be formulated as:

\[
\ln \left( \frac{C_0}{C_t} \right) = K_g t
\]  \hspace{2cm} (8)

Where, \( C_0 \) (mg/l) is the initial concentration of Cu (II) ion and \( C_t \) (mg/l) is equilibrium concentration of Cu (II) ion at time \( t \) respectively, and \( K_g \) min\(^{-1}\) is the rate constant evaluation of data has been done using linear plot of \( \ln (C_0/C_t) \) versus time. The Linear form of pseudo -Second-order equation can be formulated as:

\[
\frac{t}{q_t} = \frac{1}{K_2 q_e^2} + \frac{t}{q_e}
\]  \hspace{2cm} (9)

Where, \( q_e \) and \( q_t \) are surface loading of Cu (II) ion at equilibrium and time \( t \) respectively and \( K_2 \) (g/mg/min) is the second-order rate constant. The Linear plot of \( t/q_t \) as a function of provided not only the rate constant \( K_2 \), but also an independent evaluation of \( q_e \). The fitting of experimental data to the pseudo – first – order and the pseudo – second- order equation seemed to be quite good for ac where the calculated correlation coefficient s (R²) almost the same values

For adsorption of Cu (II) ion on to Activated Strychnos nux-vomica L the obtained results represent more conformity to pseudo-second order model (R² =0.95), the initial adsorption rate \( k_q \) for Activated Strychnos nux-vomica L (0.028mg/min).
**The Elovich equation and intra-particle diffusion model**

The Elovich model equation is generally expressed as

\[ \frac{dq_t}{dt} = \alpha \exp \left( -\beta q_t \right) \]  

(10)

Where, \( \alpha \) is the initial adsorption rate (mg g\(^{-1}\) min\(^{-0.5}\)) and \( \beta \) is the desorption constant (g/mg) during any one experiment. To simplify the Elovich equation, Chien and Clayton (1980) assumed \( \alpha t > t > 0 \) and by applying boundary conditions \( q_t = 0 \) at \( t = 0 \) and \( q_t = q \) at \( t = t \) Eq.(10) becomes:

\[ q_t = \frac{1}{\beta} \ln \left( \alpha \beta \right) + \frac{1}{\beta} \ln t \]  

(11)

Since, Cu (II) ions adsorption fits with the Elovich model, a plot of \( q_t \) Vs. \( \ln (t) \) should yield a linear relationship with a slope of \( (1/\beta) \) and an intercept of \( \ln (\alpha \beta) \). The Elovich model parameters \( \alpha, \beta \), and correlation coefficient \( (\gamma) \) are summarized in table 6.

The experimental data such as the initial adsorption rate \( (\alpha) \) adsorption constant \( (\beta) \) and the correlation coefficient \( (\gamma) \) calculated from this model indicates that the initial adsorption \( (\alpha) \) increases with temperature similar to that of initial adsorption rate \( (h) \) in pseudo-second-order kinetics models. This may be due to increase the pore or active site on the ASNVL adsorbent.

**Table 6: The Kinetic Parameters for the Adsorption of Cu (II) ion onto ASNVL**

<table>
<thead>
<tr>
<th>( C_0 )</th>
<th>Temp °C</th>
<th>( q_e )</th>
<th>( q_e )</th>
<th>( k_D )</th>
<th>( h )</th>
<th>( \alpha )</th>
<th>( \beta )</th>
<th>( \gamma )</th>
<th>K</th>
<th>( C )</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>30</td>
<td>0.0022</td>
<td>0.9952</td>
<td>8.6221</td>
<td>94.66</td>
<td>0.1503</td>
<td>0.9959</td>
<td>1.6558</td>
<td>0.994</td>
<td>0.1684</td>
</tr>
<tr>
<td>40</td>
<td>47.203</td>
<td>0.0018</td>
<td>0.9883</td>
<td>12.083</td>
<td>138.53</td>
<td>0.2206</td>
<td>0.9968</td>
<td>1.7524</td>
<td>0.995</td>
<td>0.1099</td>
</tr>
<tr>
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<td>0.9960</td>
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<td>0.9982</td>
<td>1.7762</td>
<td>0.997</td>
<td>0.0998</td>
</tr>
<tr>
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<td>18.721</td>
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<td>0.1555</td>
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<td>1.6673</td>
<td>0.999</td>
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</tr>
<tr>
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<td>98.084</td>
<td>0.0024</td>
<td>0.9946</td>
<td>12.3245</td>
<td>140.44</td>
<td>0.0734</td>
<td>0.9961</td>
<td>1.6330</td>
<td>0.998</td>
<td>0.1737</td>
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<tr>
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<td>49.232</td>
<td>0.0020</td>
<td>0.9988</td>
<td>0.719</td>
<td>151.25</td>
<td>0.1054</td>
<td>0.9987</td>
<td>1.7341</td>
<td>0.997</td>
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<tr>
<td>125</td>
<td>50.065</td>
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<td>23.156</td>
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<tr>
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<td>0.1187</td>
</tr>
<tr>
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<td>0.9887</td>
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<td>1.6795</td>
<td>0.994</td>
<td>0.1277</td>
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<tr>
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<td>130.56</td>
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<td>0.991</td>
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</tr>
<tr>
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<tr>
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<tr>
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<td>0.0013</td>
<td>0.9989</td>
<td>31.182</td>
<td>163.93</td>
<td>0.0537</td>
<td>0.9969</td>
<td>1.6428</td>
<td>0.993</td>
<td>0.1337</td>
</tr>
<tr>
<td>800</td>
<td>175.67</td>
<td>0.0025</td>
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<td>23.397</td>
<td>152.06</td>
<td>0.0451</td>
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<td>0.9994</td>
<td>1.5553</td>
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<tr>
<td>1000</td>
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<td>0.9948</td>
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<td>0.1490</td>
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<td>0.0427</td>
<td>0.9963</td>
<td>1.6051</td>
<td>0.992</td>
<td>0.1408</td>
</tr>
</tbody>
</table>

For adsorption of Cu (II) ion on to Activated Strychnos nux-vomica L, the obtained results represent more conformity to second-pseudo order model \( (R^2 = 0.95) \), the initial adsorption rate \( k_r q_e^2 \) for Activated Strychnos nux-vomica L. Kinetic data for the adsorption of Cu (II) ion were also analyzed according to intra-particle diffusion model achieve can be formulated as.

\[ Q_t = k_i t^{0.5} \]  

(12)

Where, \( q_t \) is the amount of Cu (II) ion adsorbed (mg/g) at time \( t \), and \( k_i \) (mg/g min\(^{0.5}\)) is the rate constant for intra – particle diffusion. Results are shown in table 6. Usually the plot of \( q_t \) versus \( t^{0.5} \) may be distinguished in two or more steps taking place during adsorption process including instantaneous adsorption stage by external mass transfer (first sharper portion), intra-particle diffusion which is the rate controlling stage (second portion as the gradual adsorption stage) and the final equilibration of age. Where, the intra – particle diffusion starts to slow down due to extremely low solute concentration in solution (the third portion).

**Adsorption Thermodynamics**

The thermodynamic parameters for the adsorption of Cu (II) ions by Activated Strychnos nux-vomica L were determined using the following equations:

\[ K_0 = q_e/C_e \]  

(13)

\[ \Delta G^o = – RT \ln K_0 \]  

(14)

\[ \ln K_0 = (\Delta S^o/R) – (\Delta H^o/RT) \]  

(15)

Where, \( K_0 \) is the distribution coefficient for the adsorption in g/L, \( \Delta G^o \) is the Gibbs free energy in J/mol, \( R \) is the universal gas constant in J/mol K, \( T \) is the absolute temperature in K, \( \Delta S^o \) is the entropy change in J/mol K and \( \Delta H^o \) is the enthalpy change in kJ/mol. The values of Gibbs free energy \( (\Delta G^o) \) for various temperatures were calculated from the experimental data. The values of enthalpy change \( (\Delta H^o) \) and entropy change \( (\Delta S^o) \) were estimated from the slope and intercept of the plot of \( \ln K_0 \) Vs \( 1/T \). The estimated thermodynamic parameters were tabulated and shown in table 5. The negative values of Gibbs free energy change \( (\Delta G^o) \) obtained for the adsorption of Cu
(II) ions by Activated Strychnos nux-vomica L at various temperatures had shown the spontaneous nature of the adsorption process.

**Table 5: Thermodynamic Parameter for the Adsorption of Cu (II) ion onto ASNVL**

<table>
<thead>
<tr>
<th>(C)</th>
<th>θ</th>
<th>∆G°</th>
<th>∆H°</th>
<th>∆S°</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>-5376.67</td>
<td>-5845.4</td>
<td>-6057.41</td>
<td>1.7360</td>
</tr>
<tr>
<td>50</td>
<td>-5292.81</td>
<td>-5631.9</td>
<td>-6161.48</td>
<td>3.6496</td>
</tr>
<tr>
<td>75</td>
<td>-3744.83</td>
<td>-4494.8</td>
<td>-6190.05</td>
<td>6.3538</td>
</tr>
<tr>
<td>100</td>
<td>-2538.41</td>
<td>-5390.4</td>
<td>-2554.5</td>
<td>8.6410</td>
</tr>
<tr>
<td>125</td>
<td>-1375.76</td>
<td>-2840.56</td>
<td>18.286</td>
<td>65.38</td>
</tr>
</tbody>
</table>

The positive values of enthalpy change (ΔH°) obtained for the adsorption of Cu (II) ions by Activated Strychnos nux-vomica L at various temperatures indicated that the adsorption reactions were endothermic. The positive values of entropy change (ΔS°) for the adsorption of Cu (II) ions by Activated Strychnos nux-vomica L at various temperatures showed the increased randomness at solid liquid interphase during the sorption processes of Cu (II) ions on the adsorbent ASNVL. This is a direct consequence of (i) opening up of structure of adsorbent beads (ii) enhancing the mobility and extent of penetration within the adsorbent beads and (iii) overcoming the activation energy barrier and enhancing the rate of intra-particle diffusion.

The adsorption of Cu (II) ions by Activated Strychnos nux-vomica L slightly increased when temperature was raised up to 60°C. It might be due to the generation of new active sites on the adsorbent surface and also due to the increased rate of pore diffusion. It showed that the adsorption processes of Cu (II) ions by Activated Strychnos nux-vomica L were endothermic reactions and physical in nature which involved the weak forces of attraction between the sorbate-sorbent molecules.

**Desorption studies**

Desorption studies help to elucidate the nature of adsorption and recycling of the spent adsorbent and the Cu (II) ions. If the adsorbed Cu (II) ions can be desorbed using neutral pH water, then the attachment of the Cu (II) ion of the adsorbent is by weak bonds. The effect of various reagents used for desorption studies. The results indicate that hydrochloric acid is a better reagent for desorption, because we could get more than 90% removal of adsorbed Cu (II) ion. The reversibility of adsorbed Cu (II) ion in mineral acid or base is in agreement with the pH dependent results obtained. The desorption of Cu (II) ion by mineral acids and alkaline medium indicates that the Cu (II) ion was adsorbed onto the ASNVL through physisorption as well as by chemisorptions mechanisms.

**CONCLUSION**

The adsorption of Cu (II) ions on the adsorbent was found to be initially concentration- and temperature dependent, and followed both the Freundlich and Langmuir isothermal adsorption. Moreover, R, a dimensionless separation factor of an equilibrium parameter, was far less than 0.1 indicating the favorable adsorption. The concentration helped to increase the equilibrium adsorption capacity, and higher temperature favored the adsorption. The positives values for ΔH° indicated that the process was endothermic. The positive values of entropy ΔS° suggested some structural changes in the adsorbate and adsorbent.

**ACKNOWLEDGEMENT**

The authors sincerely thank the University Grants Commission, New Delhi for providing the fund from Major Research Project.

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Source of support: University Grants Commission, New Delhi
Conflict of interest: None Declared