INTRODUCTION

Textile industries release large quantities of wastewater at risk of toxicity. The wastewater has low biodegradability, which makes biological treatments impractical and agricultural byproducts, and this is a source of environmental degradation. Adsorption is a promising technique due to the simplicity of its use as well as its low cost compared to other applications in the bleaching process cost. This is particularly true if the adsorbent is cheap and readily available.

Several adsorbents are used for the treatment of these wastewaters such as orange peels, banana peels, eggshells, sawdust, date seeds, clays and tea waste. In our study, we tried to evaluate the effectiveness of removal of methylene blue on waste from food, artichoke waste.

MATERIALS AND METHODS

The adsorbent used in this work is artichoke waste which was washed, then dried in an oven at 100 °C for 24 hours. It was crushed, then carbonized at 650 °C for one hour and a half, then sieved to obtain two different types of fractions: the first fraction is characterized by a...
diameter smaller than 80 microns (d <80 microns),
and the second fraction with a diameter of between
80 microns and 2 mm (80 microns <d <2mm).

The dye in this study was considered the
methylene blue; Figure 1 shows the molecular
structure. The stock solution of 100 mg/l was
prepared by dissolving 100 mg of the dye in distilled
water. The colored solutions of different
concentrations used in this study were prepared by
the process of dilution using distilled water.

With draws over time made it possible to
monitor the concentration of dye remaining in
solution. The residual concentration was
determined from a calibration curve, analyzed by a
UV / visible spectrometer (Shimadzu UV mini-1240).

RESULTS AND DISCUSSION

Effect of particle size

Figure 2 shows the influence of the particle
size of the adsorbent on the adsorption of methylene
blue. When we used two types of fraction, the first
fraction with the particle size less than 80 microns,
and the second fractions between 80 microns and
2 mm, it shows that the adsorption is fast and
relatively important for the fine particles (G ≤80
microns). This could be explained by the fact that
the importance of adsorption depends on extern
surface of particles; the smaller the size of particles
is, the more important the supplied surfaces of
exchanges are favoring a big spread of the dye to
the adsorbent. We take into account this result and
we are going to continue to work on this size.

Effect of concentration

To study the influence of the concentration
of the adsorbent material on the fixation of the dyes,
tests were conducted with variable concentrations
and other constant parameters. The results are
shown in Figure 4.

Modeling of adsorption kinetics

The first order model is generally
expressed as:

\[ \ln(q_e - q_t) = \ln(q_e) - k_{app} t \]  \( \ldots(1) \)

This model suggests the existence of a
Chimisorption [7], an exchange of electrons
between such a molecule of adsorbate and
adsorbent solid. It is represented by the following
formula:
\[ \frac{dq_t}{dt} = k_{2\text{app}} \cdot (q_e - q_t)^2 \]  \hspace{1cm} \ldots(2)

\( K_2 \): constant of speed of adsorption of the model pseudo second order (g.mg\(^{-1}\).min\(^{-1}\))
\( q_t \): The adsorption capacity at the time \( t \).
\( q_e \): The adsorption capacity at equilibrium.

The integration of equation (2) gives:

\[ \frac{1}{q_t} = \frac{1}{K_{2\text{app}}} \cdot \frac{1}{q_e} + \frac{1}{q_e} \]  \hspace{1cm} \ldots(3)

The values for the constants \( K_1 \), \( K_2 \) and the factors of correlation are grouped on Table 1 and table 2.

**Table 1: The parameters of the kinetic model of the first order**

<table>
<thead>
<tr>
<th>( m=1\text{g/l} ; C_0=5\text{mg/l} )</th>
<th>( K_1 )</th>
<th>( q_e )</th>
<th>( R^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( m=1\text{g/l} ; C_0=10\text{mg/l} )</td>
<td>0.0117</td>
<td>0.1525</td>
<td>0.2422</td>
</tr>
<tr>
<td>( m=1\text{g/l} ; C_0=20\text{mg/l} )</td>
<td>0.0285</td>
<td>1.1134</td>
<td>0.9788</td>
</tr>
<tr>
<td>( m=0.9\text{g/l} ; C_0=10\text{mg/l} )</td>
<td>0.0282</td>
<td>3.1474</td>
<td>0.976</td>
</tr>
<tr>
<td>( m=1.1\text{g/l} ; C_0=10\text{mg/l} )</td>
<td>0.0367</td>
<td>1.7130</td>
<td>0.6337</td>
</tr>
<tr>
<td>( m=1.25\text{g/l} ; C_0=10\text{mg/l} )</td>
<td>0.0184</td>
<td>2.6286</td>
<td>0.9981</td>
</tr>
</tbody>
</table>

**Table 2: The parameters of the kinetic model of the second order**

<table>
<thead>
<tr>
<th>( m=1\text{g/l} ; C_0=5\text{mg/l} )</th>
<th>( K_1 )</th>
<th>( q_e )</th>
<th>( R^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( m=1\text{g/l} ; C_0=10\text{mg/l} )</td>
<td>0.6182</td>
<td>6.182</td>
<td>0.8248</td>
</tr>
<tr>
<td>( m=1\text{g/l} ; C_0=20\text{mg/l} )</td>
<td>0.1185</td>
<td>0.1185</td>
<td>0.9856</td>
</tr>
<tr>
<td>( m=0.9\text{g/l} ; C_0=10\text{mg/l} )</td>
<td>0.1269</td>
<td>0.1269</td>
<td>0.9835</td>
</tr>
<tr>
<td>( m=1.1\text{g/l} ; C_0=10\text{mg/l} )</td>
<td>0.0522</td>
<td>0.0522</td>
<td>0.982</td>
</tr>
<tr>
<td>( m=1.25\text{g/l} ; C_0=10\text{mg/l} )</td>
<td>0.0792</td>
<td>0.0792</td>
<td>0.9801</td>
</tr>
</tbody>
</table>

**Isotherm of adsorption**

**Model of Langmuir**

This model is defined by a maximum capacity of adsorption that has been bound to the cover of surface sites by a monolayer. The importance of the Langmuir Isotherm is that it can be in theory applied to a perfectly uniform surface, and when there is no interaction between the adsorbed molecules\(^a\). The relation that characterizes this model is as follows:

\[ \frac{q_e}{q_m} = \theta = \frac{K_L \cdot C_s}{1 + K_L \cdot C_s} \] \hspace{1cm} \ldots(4)

\( q \): capacity of adsorption in mg/ l.
\( q_m \): Maximum capacity of adsorption in mg/ l.
\( K \): The equilibrium constant of adsorption of Langmuir in l/mg.
\( C_s \): Concentration of the adsorbate at adsorption equilibrium.

**Fig. 5: Modeling of adsorption isotherms by the equation of Langmuir**

**Table 3: Parameters of Langmuir model**

<table>
<thead>
<tr>
<th>( C_0\text{(mg/l)} )</th>
<th>( q_m )</th>
<th>( K_L )</th>
<th>( R^2 )</th>
<th>( R_L )</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>7,9617</td>
<td>13,0838</td>
<td>0.9972</td>
<td>0.0075</td>
</tr>
<tr>
<td>15</td>
<td>10,3092</td>
<td>0.9719</td>
<td>0.9813</td>
<td>0.064</td>
</tr>
<tr>
<td>20</td>
<td>15,9489</td>
<td>0.2064</td>
<td>0.9884</td>
<td>0.195</td>
</tr>
</tbody>
</table>

The viability of the adsorption can be defined from the factor of separation \( R_L \):

\[ R_L = \frac{l}{1 + K_L \cdot C_0} \] \hspace{1cm} \ldots(5)

\( R_L >1 \) conditions are unfavorable adsorption;
\( R_L <1 \) conditions are favorable adsorption;
\( R_L =0 \) adsorption is irreversible.
The factor of separation is less than 1 for all concentrations, thus the adsorption is favorable.
Model of Freundlich

This model is used in the case of possible formation of more than one monolayer of adsorption on the surface and the sites are heterogeneous with different energies of fixation.

The relationship that characterizes this model is given in the form:

\[ q_v = K_f C_e^n \]  

(6)

Q: Quantity adsorbed by gram of the solid.

C_e: Concentration of the Adsorbate at adsorption equilibrium.

K_f and n_f: Freundlich constants characteristic of a given efficiency vis-à-vis a given solute adsorbent.

Table 4: Parameters of Freundlich model

<table>
<thead>
<tr>
<th>C_e (mg/l)</th>
<th>q_m</th>
<th>K_f</th>
<th>n</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>88,517</td>
<td>6,995</td>
<td>0,1022</td>
<td>0,9963</td>
</tr>
<tr>
<td>15</td>
<td>146,422</td>
<td>5,950</td>
<td>0,215</td>
<td>0,9317</td>
</tr>
<tr>
<td>20</td>
<td>215,565</td>
<td>4,168</td>
<td>0,4126</td>
<td>0,9916</td>
</tr>
</tbody>
</table>

CONCLUSION

The study of the mechanisms of the adsorption of the methylene blue on the waste of the artichoke has been the subject of this work. The results related to the kinetics and isotherms of adsorption have been exploited to explain the method of fixation of the dye on the adsorbent. The study of the influence of the mass and the initial concentration on the kinetics showed that the process of adsorption follows the model of pseudo-second order. The adsorption capacity of a mass of the waste of artichoke increases with the increase of the initial concentration of the dye in the solution. The model of Langmuir expresses the type of adsorption; the dye molecules are adsorbed in a monolayer.

Fig. 6: Modeling of adsorption isotherms by the equation of Freundlich

REFERENCES

3. Ounas, A.; Bergach, N.; Ennaciri, K.; Yaacoubi, A.; Bacaoui, A.; "Préparation des charbons actifs à partir des déchets de l’industrie oléicole".
8. Gherbi, N.; "Etude expérimentale et