Effect of High Ionic Strength on Metal and Organic Removal Using Activated Carbon

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**ABSTRACT**

In this study, we looked into the removal of heavy metal ions copper, lead and humic acid from high salinity water using activated carbon. Experiments were carried out to determine how high ionic strength can affect the rate of adsorption of these contaminants of water. The results obtained showed that high ionic strength reduced the adsorption of copper and lead ions using activated carbon while humic acid had opposite effects on copper and lead adsorption. High ionic strength also reduced the adsorption of humic acid on activated carbon.

**INTRODUCTION**

Water shortage is a major problem in many areas. As population and industrialization increase, water supply crises in already-water-short-regions will intensify. Desalination of seawater is one of the possible methods of water recovery, especially for coastal communities.

Seawater contains about 3.5% of sodium chloride. Besides the removal of salts, it is also essential to remove heavy metal ions before it can be used domestically. Copper is commonly present and excessive intake can result in accumulation in the liver and produces gastrointestinal problems. Lead contamination can have serious consequences and especially in children, lead poisoning can be lethal.

**Humic Substances**

Dissolved organic matter (DOM) is found in all natural waters. Humic substances account for 40-60% of the DOM present. The exact mechanism in the formation of humic acid is not known but it certainly involves the degradation of plant organic matter. Humic substances act as polyelectrolyte ligands for many trace metals in solution (Rashid, 1985), hence, affect the adsorption of metals to particles. In experiments conducted, the effect of high salinity water on the adsorption of humic acid onto activated carbon is also investigated.

**Activated Carbon**

Activated carbon, because of their large surface area, micro-porous structure and high degree of surface reactivity, are considered good adsorbents for the adsorption of both organics and inorganics from water.

**EXPERIMENTS**

All chemicals used were of reagent grade.

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Filtrasorb 200 Granulated Activated Carbon (GAC) was sieved, washed with deionised water (DI), left to dry in an oven for 2 hours at 100°C and finally left to cool in an airtight glass cell containing desiccators. Samples varying from 0.05g to 1.50g were placed in 100ml solutions of 3 different compositions. The first set contained only 0.0002M copper nitrate Cu(NO\textsubscript{3})\textsuperscript{2-}, the second set contained 0.0002M Cu(NO\textsubscript{3})\textsuperscript{2-} and 3.5% sodium chloride NaCl. The third set contained 0.0002M Cu(NO\textsubscript{3})\textsuperscript{2-}, 3.5% NaCl and 10ppm humic acid. The solutions were left in an isothermal environment (25°C) and shaken for 48 hours while pH was maintained at about 6.5.

An aliquot portion was pipetted out from every sample and filtered using 0.45μm Whatman Autovial filter before carrying out analysis. Concentration of metal ions was measured using an Inductively Coupled Plasma Emission Spectroscopy (ICP).

Adsorption of lead was measured using lead nitrate Pb(NO\textsubscript{3})\textsuperscript{2-}.

**Humic Acid Adsorption**

A similar experiment was also done using a solution containing only 30ppm humic acid. Total organic carbon was tested using TOC- 500A.

**RESULTS AND DISCUSSION**

**Copper Adsorption**

The effect of high ionic strength and the presence of humic acid on the adsorption of copper ions were determined. Data obtained was fitted into the Langmuir Isotherm Equation as shown below. The Langmuir constants found from the study are listed in Table 1.

\[
q_e = \frac{q_m b C_e}{1 + b C_e}
\]

Where \(q_e\) and \(C_e\) are metal concentration in solid and solution phases. \(q_m\) and \(b\) are Langmuir constants.

<table>
<thead>
<tr>
<th></th>
<th>Cu\textsuperscript{2+}</th>
<th>Cu\textsuperscript{2+} with 3.5wt% NaCl</th>
<th>Cu\textsuperscript{2+} with 3.5wt% NaCl &amp; 10ppm humic acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>(b)</td>
<td>0.591</td>
<td>0.237</td>
<td>0.180</td>
</tr>
<tr>
<td>(q_m)</td>
<td>0.031</td>
<td>0.064</td>
<td>0.057</td>
</tr>
</tbody>
</table>

**Figure 1. Adsorption isotherms of copper adsorption.**
According to Chen and Lin (2000), higher copper adsorption was obtained with increasing ionic strength. The salt ions are attracted to the spaces between adjacently adsorbed copper ions and hence increase the packing density of adsorbed ions on the GAC. The results obtained in this experiment agree with the previous finding. Langmuir constant \( q_m \) is lower when salt was added and even lower when humic acid was also present. At high ionic strength, the adsorption of copper was greater. However, when humic acid was present, the increase in adsorption rate became less. This can be due to the humic acid forming polyelectrolyte ligands with copper ions and preventing the ions from being adsorbed by the GAC. Another possibility would be that humic acid acts as a competitor to the copper ions, occupying some of the available sites for adsorption itself.

### Lead Adsorption

The effect of high ionic strength and the presence of humic acid on the adsorption of lead ions were determined. Data obtained was fitted into the Langmuir Isotherm Equation. See Eqn (1). The Langmuir constants found from the study are listed in Table 2. The adsorption isotherms are shown in Fig 2.

<table>
<thead>
<tr>
<th></th>
<th>( \text{Pb}^{2+} )</th>
<th>( \text{Pb}^{2+} ) with 3.5wt% NaCl</th>
<th>( \text{Pb}^{2+} ) with 3.5wt% NaCl &amp; 10ppm humic acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>( b )</td>
<td>0.004</td>
<td>0.258</td>
<td>0.106</td>
</tr>
<tr>
<td>( q_m )</td>
<td>0.368</td>
<td>0.028</td>
<td>0.041</td>
</tr>
</tbody>
</table>

![Figure 2. Adsorption isotherms of lead adsorption.](image)

At high ionic strength, Langmuir constant \( q_m \) was lower. Even though many investigators have shown the presence of inorganic salts can enhance the adsorption of various species to carbon, there have been exceptions. For example, Reed et al (1992) found a decrease in cadmium removal when ionic strength was increased. Hence, it is likely that lead adsorption is also one of them. However, in the presence of humic acid and high ionic strength, \( q_m \) was higher than that when the
solution was of high ionic strength but contained no humic acid. This is probably due to the presence of humic acid functional groups which adsorb some metals.

**Humic Acid Adsorption**

Humic acid can also be removed using GAC. The effect of high ionic strength on the adsorption of humic acid was investigated. From the results are shown in Fig 3, it can be seen that high ionic strength reduced the adsorption of humic acid.

![Figure 3. Adsorption isotherms of humic acid adsorption.](image)

**CONCLUSIONS**

Higher copper adsorption and lower lead adsorption was obtained with high ionic strength. Presence of humic acid reduced copper adsorption and increased lead adsorption in high salinity water. Adsorption of humic acid itself is reduced by high ionic strength.

**REFERENCES**


