Simultaneous adsorption of nickel ions and humic acid onto an activated carbon

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Abstract

Simultaneous adsorption of nickel ions and humic acid (HA) from Aldrich onto an activated carbon is studied in this research. It is found that the nickel adsorption in the absence of HA increases as the pH is increased, but decreases after pH reaches about 6. Nickel-HA adsorption also varies when HA concentration differs. The ionic strength also has a positive effect on the nickel adsorption. The zinc and copper ions do not affect the nickel adsorption significantly.

1. INTRODUCTION

The objective of this study was to investigate the mechanisms of the adsorption of nickel ions and HA onto an activated carbon simultaneously. In this study, nickel was selected to be studied, because it always exists in the industrial wastewater due to its wide application in a variety of industries. The important factors in the adsorption, such as pH, HA concentration, ionic strength, and competitive metal ions, were all considerate.

Nickel is widely used in varies industries (Bansal, 1996) and the concentrations in industrial wastewaters can range from 3.4 to 900 mg/L Compared to the maximum contaminant limit in potable water is only 50 μg/L in accordance with the standards of European Economic Community (Eswed, 2006), Such high concentration causes harmful effect on creatures.

Humic acid is one of the major components of humic substances. Due to its strong affinity to metal ions and complex ability, the HA in aqueous solutions can change the metal adsorptive behavior. So the simultaneous adsorption of nickel ions and HA onto activated carbons is worth to be studied.

2. EXPERIMENTAL SECTIONS

2.1 Materials

Charcoal activated granular carbon which was produced by SINO Chemical CO (PTE) LTD was used. After being washed for several times by HCL and DI water to remove the impurities, the carbon was dried in a drying oven at 65°C for 24 h and stored in a desiccator for use. sodium chloride, zinc chloride, copper chloride,
hydrochloric acid, nitric acid, and sodium hydroxide are from Merck (Germany). HA (sodium salt) and was obtained from Aldrich (Milwaukee, WI). All chemicals used were of reagent grade.

2.2 Adsorption Experiments

A series of batch adsorption equilibrium experiments was conducted to obtain the factors to influence the nickel adsorption with or without HA. The general experimental procedures are described below: Nickel and/or HA solutions with or without pH control by dropping HCl and NaOH solutions were prepared. The ionic strength was adjusted by the NaCl. The carbon was then added into the solutions. The flasks were placed in a shaker and shaken for 96 h at 25 °C to reach equilibrium. The concentration of nickel ions was measured by inductively coupled plasma emission spectroscopy (ICP-ES) (Perkin–Elmer Optima 3000, USA). The pH was measured by an Accumet Basic pH meter (Fisher Scientific, USA).

The Langmuir equations was used to fit the isothermal adsorption data,

\[
q_e = \frac{q_{\text{max}}bC_e}{1+bC_e}
\]  

Where \(q_e\) is the concentration of adsorbate in the solid phase at equilibrium (mg/g), \(C_e\) is the concentration of adsorbate in liquid phase at equilibrium (mg/L), \(q_{\text{max}}\) and \(b\) are the Langmuir constants.

3. RESULTS AND DISCUSSION

3.1 pH dependence on Nickel adsorption

After shaking for 96 hours, all the samples are tested. The results can be observed from Figure 1. At the same time period, the adsorption efficiency increases to 15% as the pH increases from 3.5 to 6, and then decrease a little bit after pH reaches 6. According to the old studies done before, the maximum adsorption was at both acidic and basic pH ranges. However the rate of adsorption in basic pH was much faster (Bansal, 1996).
3.2 Effect of humic acid (HA) concentration on nickel adsorption

![Effect of HA concentration on Nickel adsorption](image1)

The effect of HA concentration on nickel adsorption is demonstrated in Figure 2a and 2b. Different concentrations of HA play different roles in nickel adsorption. An increase in pH values can also help to enhance the nickel uptake. As shown in the figure 2a, in the metal adsorption, there are two critical HA concentration amounts (C1 and C2) of 2 mg/L and 6mg/L respectively. When the HA concentration is lower than the C1, the nickel adsorption decreases as the HA concentration is increased; however, when the HA concentration is between C1 and C2, the nickel uptake is enhanced as the HA concentration is increased. However, after HA concentration reached C2, an increase of HA concentration causes a decrease in nickel uptake. The similar results can be found in the previous study on the copper-HA adsorption (Chen, 2004).
3.3 Effect of ionic strength on Nickel adsorption in the presence of HA

![Effect of ionic strength on Nickel adsorption in the presence of HA](image)

It is found in Figure 3 that an increase in solution ionic strength (NaCl) can enhance the nickel adsorption onto the HA–carbon. It has been reported that higher ionic strength can slightly increase cation adsorption onto activated carbons due to compression of the electrostatic double layer (Bjelopavlic, 1999; Zhou, 1994). The increase in ionic strength can increase the HA adsorption (Stumm, 1996), which is also due to the compression of the EDL (Bjelopavlic, 1999; Zhou, 1994). As more HA macromolecules are adsorbed onto the surfaces of carbon at higher ionic strength, more adsorptive sites are thus formed for the metal adsorption. As a result, higher metal uptake onto the HA–carbon is observed.

3.4 Effect of competitive metal species on nickel–HA adsorption

![Effect of competitive metals on nickel-HA adsorption](image)

Figure 4 demonstrates that existence of zinc or copper ions has very slightly effects on the nickel adsorption in the presence of HA. This finding is similar to that in the presence of zinc or cobalt (in the absence of HA) found in other study (Chen, 2001). The effect of the presence of competing metal ions on the nickel adsorption
can be attributed to the different affinities of these metal ions to the adsorptive sites on the HA–carbon.

3.5 Nickel adsorption kinetics with/without HA

Nickel adsorption kinetic experiments were carried out at last. The results of nickel adsorption kinetics in the absence and the presence of HA are shown in Figure 5. It is observed that the presence of HA extends the equilibrium time required. In the absence of HA, the nickel adsorption achieves equilibrium in approximately 65 hours, while the adsorption cannot reach the equilibrium until 80 hours in the presence of HA. It can be observed that high percentage of the nickel adsorption occurs in the first 25 to 28 hours in the absence and the presence of HA, followed by a long period of slow adsorption process.

4. CONCLUSION

It is found that the nickel adsorption in the absence of HA increases as the pH is increased, but decreases after pH reaches about 6. There exist two critical HA concentration amounts for nickel adsorption. The absorption effect is decreased at first when HA concentration increases until it reaches 3mg/L; then the adsorption increases as the HA concentration increases until it reaches the 6mg/L. The ionic strength also has a positive effect on the nickel adsorption. However, the presences of zinc or copper ions do not affect the nickel adsorption significantly.

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6. REFERENCES


